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**UTILITY  
PATENT APPLICATION  
TRANSMITTAL**

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	94100411(EP)USC1X1C1C1
First Inventor	Adrian P. Wise
Title	Multistandard Video Decoder...Relating Thereto
Express Mail Label No.	EL443264059US

**APPLICATION ELEMENTS**

See MPEP chapter 600 concerning utility patent application contents.

1. ☒ Fee Transmittal Form (e.g., PTO/SB/17)  
(Submit an original and a duplicate for fee processing)
2. ☐ Applicant claims small entity status.  
See 37 CFR 1.27.
3. ☒ Specification [Total Pages 675]  
(preferred arrangement set forth below)
  - Descriptive title of the invention
  - Cross Reference to Related Applications
  - Statement Regarding Fed sponsored R & D
  - Reference to sequence listing, a table, or a computer program listing appendix
  - Background of the Invention
  - Brief Summary of the Invention
  - Brief Description of the Drawings (if filed)
  - Detailed Description
  - Claim(s)
  - Abstract of the Disclosure
4. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets 124]
5. Oath or Declaration [Total Pages ]
  - a. ☐ Newly executed (original or copy)
  - b. ☒ Copy from a prior application (37 CFR 1.63 (d))  
(for continuation/divisional with Box 17 completed)
    - i. ☐ **DELETION OF INVENTOR(S)**  
Signed statement attached deleting inventor(s)  
named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. ☐ Application Data Sheet. See 37 CFR 1.76

**ADDRESS TO:**Assistant Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

7. ☐ CD-ROM or CD-R in duplicate, large table or Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
  - a. ☐ Computer Readable Form (CRF)
  - b. Specification Sequence Listing on:
    - i. ☐ CD-ROM or CD-R (2 copies); or
    - ii. ☐ paper
  - c. ☐ Statements verifying identity of above copies

**ACCOMPANYING APPLICATION PARTS**

9. ☒ Assignment Papers (cover sheet & document(s))
10. ☐ 37 CFR 3.73(b) Statement (when there is an assignee) ☐ Power of Attorney
11. ☐ English Translation Document (if applicable)
12. ☒ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
13. ☒ Preliminary Amendment
14. ☒ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
15. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. ☒ Other: Communication

17. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

☒ Continuation ☐ Divisional ☐ Continuation-in-part (CIP)

of prior application No.: 09,307,239

Prior application information:

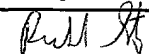
Examiner Follansbee

Group / Art Unit: 2783

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

**18. CORRESPONDENCE ADDRESS**☒ Customer Number or Bar Code Labelor ☐ Correspondence address below

Name				
Address	022887			
City	PATENT TRADEMARK OFFICE	State		Zip Code
Country		Telephone		Fax

Name (Print/Type)	Richard Stokely	Registration No. (Attorney/Agent)	40,383
Signature		Date	10/12/00

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*Patent fees are subject to annual revision*

*Complete if Known*

Application Number	Not Yet Known
Filing Date	Herewith
First Named Inventor	Adrina P. Wise
Examiner Name	J. Follansbee (anticipated)
Group / Art Unit	2783 (anticipated)
Attorney Docket No.	94100411(EPI)USC1X1C1C1 PDDD

<b>TOTAL AMOUNT OF PAYMENT</b>	<b>(\$)</b>	<b>1388.00</b>
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## METHOD OF PAYMENT

1. ☒ The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number	04-1175
Deposit Account Name	DISCOVISION ASSOCIATES

- ☒ Charge Any Additional Fee Required ☐ Applicant claims small entity status. See 37 CFR §1.27

2 ☐ **Payment Enclosed:**

- ☐
- Check
- ☐
- Credit Card
- ☐
- Money Order
- ☐
- Other

### FEE CALCULATION

### 1. BASIC FILING FEE

Large Entity Fee Code	Small Entity Fee Code	Fee (\$)	Fee (\$)	Fee Description	Fee Paid
101	710	201	355	Utility filing fee	690.00
106	320	206	160	Design filing fee	
107	490	207	245	Plant filing fee	
108	710	208	355	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUB TOTAL (1)	(\$)	690.00
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## 2. EXTRA CLAIM FEES

	Extra Claims	Fee from Below	Fee Paid
Total Claims <input type="text" value="41"/>	-20**= <input type="text" value="21"/>	x <input type="text" value="18.00"/>	= <input type="text" value="378.00"/>
Independent Claims <input type="text" value="7"/>	-3**= <input type="text" value="4"/>	x <input type="text" value="80.00"/>	= <input type="text" value="320.00"/>
Multiple Dependent			

\*\*or number previously paid, if greater; For Reissues, see below

Large Fee Code	Entity Fee (\$)	Small Fee Code	Entity Fee (\$)	Fee Description
103	18	203	9	Claim in excess of 20
102	80	202	40	Independent claims in excess of 3
104	270	204	135	Multiple dependent claim, if not paid
109	80	209	40	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

<b>SUBTOTAL (2)</b>	<b>(\$)</b>	<b>698.00</b>
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**FEE CALCULATION (continued)**

### 3. ADDITIONAL FEES

Large Fee Code	Entity Fee (\$)	Small Fee Code	Entity Fee (\$)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet.	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for ex parte reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	390	216	195	Extension for reply within second month	
117	890	217	445	Extension for reply within third month	
118	1,390	218	695	Extension for reply within fourth month	
128	1,890	228	945	Extension for reply within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,240	241	620	Petition to revive - unintentional	
142	1,240	242	620	Utility issue fee (or reissue)	
143	440	243	220	Design issue fee	
144	600	244	300	Plant issue fee	
122	130	122	130	Petitions to the Commisisoner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	710	246	355	Filing a submission after final rejection (37CFR §1.129(a))	
149	710	249	355	For each additional invention to be examined (37CFR §1.129(b))	
179	710	279	355	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify)

\* Reduced by Basic Filing Fee Paid

SUBTOTAL (3)	(\$)	\$
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## SUBMITTED BY

Complete (if applicable)

Typed or Printed Name	Richard Stokey
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Reg. Number	40.383
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Signature

Date \_\_\_\_\_

10/12/00

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04-1175

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October 12, 2000

VIA EXPRESS MAIL

Document Control No. FSVVO

BOX: Patent Application  
Assistant Commissioner for Patents  
Washington D.C. 20231

RE: U. S. Patent Application Ser. No. Not Yet Known  
MULTISTANDARD VIDEO DECODER AND DECOMPRESSION SYSTEM  
FOR PROCESSING ENCODED BIT STREAMS INCLUDING START  
CODES AND METHODS RELATING THERETO  
Atty Docket No. 94100411(EP)USC1X1C1C1 PDDD

Sir:

Enclosed for filing please find the following:

1. Utility Patent Application Transmittal for 1.53(b)
2. Fee Transmittal Form
3. Preliminary Amendment
4. Supplemental Declarations from parent application of Adrian Wise, Martin Sotheran, Will Robbins, Mark Jones, Peter Claydon, Kevin Boyd, and Helen Finch
5. Communication – Cross Reference to Related Applications
6. Supplemental Information Disclosure Statement; PTO-1449's
7. Notice of Recordation of Assignment Document from parent application
8. Assignments from parent application
9. Communication – Submission of Formal Drawings
10. Formal Drawings 1-169 on 124 sheets
11. Specification including 674 pages
12. Certificate of Express Mail No. EL443264059US dated October 12, 2000
13. Postcard (control #FSVZ1)

Please indicate on the enclosed pre-addressed, postage pre-paid postcard the date of receipt of the enclosed materials and mail the postcard to acknowledge receipt of this transmittal.

Very truly yours,

DISCOVISION ASSOCIATES

Richard Stokey  
Patent Prosecution Attorney

RS:sd

Encls

\\TCPSERV01\GRPDIRS\ABG\PPD\PDD\941004--(EP)USC1X1C1C1\ptocvr\_101.doc

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:  
Adrian P. Wise et al.

§ Art Unit: 2783

§

§

Continuation of Serial No. 09/307,239

§ Examiner: Follansbee, J.

§

Filed: (concurrently with specification)

§ Attorney Docket No.:

94100411(EP)USC1X1C1C1 PDDD

§

For: MULTISTANDARD VIDEO  
DECODER AND DECOMPRESSION  
SYSTEM FOR PROCESSING  
ENCODED BIT STREAMS  
INCLUDING START CODES AND  
METHODS RELATING THERETO

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PRELIMINARY AMENDMENT

Box PATENT APPLICATION  
Assistant Commissioner for Patents  
Washington DC 20231

FILING OF CORRESPONDENCE BY EXPRESS MAIL UNDER 37 C.F.R. § 1.10	
EL443264059US	10/12/00
Express Mail Label Number	Date of Deposit

Sir:

Prior to issuance of Serial Number 09/307,239 filed on October 7, 1997, and entitled MULTISTANDARD VIDEO DECODER AND DECOMPRESSION SYSTEM FOR PROCESSING ENCODED BIT STREAMS INCLUDING START CODES AND METHODS RELATING THERETO, applicant wishes to file a new continuing application thereon.



**In the Specification:**

On page 1, line 1, please delete "DATA PIPELINE SYSTEM AND DATA ENCODING METHOD" and in place thereof, please insert new title:

--MULTISTANDARD VIDEO DECODER AND DECOMPRESSION SYSTEM FOR PROCESSING ENCODED BIT STREAMS INCLUDING START CODES AND METHODS RELATING THERETO--.

On page 1, lines 2-8, please delete "This is a continuation-in-part application of U.S. Serial No. (not yet known) filed February 2, 1995, which is a continuation application of Serial No. 08/082,291 filed June 24, 1993. This application claims priority from EPO Application No. 92306038.8 filed June 30, 1992, British Application No. 9405914.4 filed March 24, 1994 and British Application No. (not yet known) filed February 28, 1995." and in place thereof please insert the following heading and paragraph:

--CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. Serial No. 09/307,239 filed October 7, 1997, which is a continuation of U.S. Serial No. 08/400,397 filed March 7, 1995, which is a Continuation-In-Part of U.S. Serial No. 08/382,958 filed February 2, 1995, now abandoned, which is a continuation of U.S. Serial No. 08/082,291 filed June 24, 1993, now abandoned.--

**In the Claims:**

Please add the following claims:

1           1.     A pipelined video decoder and decompression system for handling a  
2 plurality of separately encoded bit streams arranged as a single bit stream of digital  
3 bits, comprising:

4               a start code detector responsive to said single serial bit stream for generating  
5 control tokens and data tokens, a said token including a plurality of data words, each  
6 data word having an extension bit which indicates a presence of additional words  
7 therein so that said start code detector detects overlapping start codes in said bit  
8 stream, a first start code thereby being ignored and a second start code used to  
9 create start code tokens;

10           a token decode circuit interactively associated with said start code detector,  
11 said token decode circuit for recognizing certain of said tokens as control tokens  
12 pertinent to a respective processing stage and for passing unrecognized control  
13 tokens to a succeeding stage; and

14           a reconfigurable decode and parser unit responsive to a recognized control  
15 token for reconfiguring a particular stage to handle an identified data.

1           2.     The system as recited in claim 1, further comprising first and second  
2 registers, said first register positioned as an input of said decode and parser unit and  
3 said second register positioned as an output of said decode and parser unit.

1           3.     The system according to claim 1 wherein said single serial bit stream of  
2 digital bits includes separately encoded pairs of control codes and corresponding  
3 data carried therein.

1           4.     The system according to claim 1 wherein said tokens are altered by  
2 said processing stages

1           5. A method of processing video data, comprising:  
2     receiving video data having portions encoded in accordance with respective  
3 different video standards, the plurality of video standards defining corresponding start  
4 codes;  
5     identifying one of the start codes included in the received video data; and  
6     processing the received video data in accordance with the video standard  
7 corresponding to the identified start code.

1           6.     The method of claim 5 wherein the start code includes an H.261 picture  
2 start code.

1           7.     The method of claim 5 wherein the start code includes an MPEG (Motion  
2 Pictures Experts Group) start code.

1           8.     The method of claim 5 wherein the start code includes a JPEG (Joint  
2 Photographic Experts Group) start of scan marker.

1           9. The method of claim 5 wherein the start code includes a start code used  
2 by a video format that encodes spatial and temporal video data.

1           10. The method of claim 5 wherein the step of processing includes decoding  
2 the received video data.

1           11. The method of claim 5 wherein the step of processing includes  
2 constructing one or more images for display based on the received video data.

1           12. The method of claim 5 wherein the step of processing includes  
2 rearranging one of the portions of received video data into an arrangement that  
3 complies with a different one of the video standards.

1           13. A method of processing video data, comprising:  
2 receiving a first set of video data encoded in accordance with a first video  
3 standard and having a first start code defined by the first video standard;  
4 determining the video standard of the first set of video data by identifying the  
5 first start code included in the first set of video data;  
6 processing the first set of video data in accordance with the first video  
7 standard;  
8 receiving a second set of video data encoded in accordance with a second  
9 video standard and having a second start code defined by the second video  
10 standard;  
11 determining the second video standard of the second set of video data by  
12 identifying the second start code included in the second set of video data; and

13           processing the second set of video data in accordance with the second video  
14   standard.

1           14. The method of claim 13 wherein the step of processing includes  
2   decoding.

1           15. The method of claim 13 wherein one of the first or the second video  
2   standards includes one of either: an MPEG (Motion Pictures Experts Group)  
3   standard, a JPEG (Joint Photographic Experts Group) standard, or an H.261  
4   standard.

1           16. A method of processing encoded video data, comprising:  
2       receiving video data having portions encoded with respective different video  
3   standards;  
4       determining a video standard from the respective different video standards  
5   based on one of start codes embedded in the video data;  
6       generating tokens demarcating the received video data; and  
7       processing the received video data in accordance with the tokens.

1           17. The method of claim 16 wherein the video standards include at least one  
2   of the following: MPEG (Motion Pictures Experts Group), H.261, and JPEG (Joint  
3   Photographic Experts Group).

1           18. The method of claim 16 wherein the tokens include a picture start token.

1 19. The method of claim 16 wherein the tokens include a picture end token.

1 20. A method of processing encoded video data at a video data processing  
2 stage, comprising:

3 receiving a start identification of one of several video standards of the encoded  
4 video data;

5 configuring the video data processing stage based on the received start  
6 identification; and

7 processing the video data at the configured video data processing stage in  
8 accordance with the received start identification.

1 21. The method of claim 20 wherein the video data processing stage includes  
2 a decoder.

1 22. The method of claim 21 wherein the decoder includes a Huffman  
2 decoder.

1 23. The method of claim 20 wherein the video data processing stage includes  
2 an inverse quantizer.

1 24. The method of claim 20 wherein the step of configuring includes  
2 determining tables used by the video data processing stage.

1 25. The method of claim 20 wherein the video data processing stage  
2 programmatically alters electrical signals representing the encoded video data.

1           26. A method of processing video data, comprising:  
2           receiving a first video data code or marker corresponding to a first video  
3 standard;  
4           searching video data for the received video code or marker;  
5           receiving a second video data code or marker corresponding to a second  
6 video standard; and  
7           searching video data for the second video data code or marker.

1           27. The method of claim 26 wherein the first video standard includes one of  
2 the following: MPEG (Motion Pictures Experts Group, JPEG (Joint Photographic  
3 Experts Group), and H.261.

1           28. The method of claim 26 wherein the video data code or marker  
2 includes at least one of the following: a picture start code, a sequence start code, a  
3 slice start code, a start of scan marker, and a group start code.

1           29. A method of processing video data, comprising:  
2           receiving video data;  
3           determining a video standard associated with the video data;  
4           generating one or more tokens for controlling decoding of the received video  
5 data by a decoding pipeline; and  
6           decoding the received video data in the decoding pipeline.

1           30. The method of claim 29 wherein determining the video standard  
2 includes identifying a start code or marker in the received video data.

1           31. The method of claim 29 wherein the video standard includes at least  
2 one of the following: MPEG, JPEG, and H.261.

1           32.       The method of claim 29 wherein the step of generating includes  
2 generating one or more tokens that configure the decoding pipeline for processing of  
3 the determined video standard.

1           33.       The method of claim 29 wherein the step of generating includes  
2 generating one or more tokens demarcating the received video data.

1           34.       The method of claim 29 wherein the demarcating the received video  
2 data includes identifying one or more of the following: a picture start, a picture end, a  
3 sequence start, and a group start.

1           35.       The method of claim 29 wherein the pipeline includes a Huffman  
2 decoder.

1           36.       The method of claim 29 wherein the pipeline includes instructions for  
2 an inverse discrete cosine transform upon a portion of the received video data.

1           37.       The method of claim 29 wherein one of the one or more tokens  
2 includes a picture start token that identifies the start of a picture in the received video  
3 data.

1           38.       The method of claim 29 wherein one of the one or more tokens  
2 includes a picture end token that identifies the end of a picture in the received video  
3 data.



1           39.       The method of claim 29 wherein one of the one or more tokens  
2 includes a coding standard token that identifies the video standard of the received  
3 video data.

1           40.       The method of claim 29 wherein one of the one or more tokens  
2 includes a flush token that resets stages in the decoding pipeline.

1           41.       The method of claim 29 wherein clearing the pipeline includes  
2 resetting pipeline elements for reception of subsequent video data.

#### REMARKS

Should the Examiner believe that contact with Applicant's attorney would be beneficial to the disposition of this application, he is invited to contact Applicant's attorney at the telephone number listed below. The Commissioner is hereby authorized to charge payment of any fees associated with this communication or credit any overpayment to Deposit Account No. 94-1175.

Respectfully submitted,



Date: 10/12/00

Richard Stokey  
Reg. No. 40,383

DISCOVISION ASSOCIATES  
INTELLECTUAL PROPERTY DEVELOPMENT  
P.O. Box 19616  
Irvine, California 92623  
(949) 660-5006

## DATA PIPELINE SYSTEM AND DATA ENCODING METHOD

This is a continuation-in-part application of U.S. Serial No. (not yet known) filed February 2, 1995, which is a continuation application of Serial No. 08/082,291 filed  
5 June 24, 1993. This application claims priority from EPO Application No. 92306038.8 filed June 30, 1992, British Application No. 9405914.4 filed March 24, 1994 and British Application No. (not yet known) filed February 28, 1995.

### BACKGROUND OF THE INVENTION

10 The present invention is directed to improvements in methods and apparatus for decompression which operates to decompress and/or decode a plurality of differently encoded input signals. The illustrative embodiment chosen for  
15 description hereinafter relates to the decoding of a plurality of encoded picture standards. More specifically, this embodiment relates to the decoding of any one of the well known standards known as JPEG, MPEG and H.261.

A serial pipeline processing system of the present invention comprises a single two-wire bus used for carrying  
20 unique and specialized interactive interfacing tokens, in the form of control tokens and data tokens, to a plurality of adaptive decompression circuits and the like positioned as a reconfigurable pipeline processor.

Video compression/decompression systems are generally  
25 well-known in the art. However, such systems have generally been dedicated in design and use to a single compression standard. They have also suffered from a number of other inefficiencies and inflexibility in overall system and subsystem design and data flow management.

30 Examples of prior art systems and subsystems are enumerated as follows:

One prior art system is described in United States Patent No. 5,216,724. The apparatus comprises a plurality of compute modules, in a preferred embodiment, for a total of  
35 four compute modules coupled in parallel. Each of the

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compute modules has a processor, dual port memory, scratch-  
pad memory, and an arbitration mechanism. A first bus  
couples the compute modules and a host processor. The device  
comprises a shared memory which is coupled to the host  
5 processor and to the compute modules with a second bus.

United States Patent No. 4,785,349 discloses a full  
motion color digital video signal that is compressed,  
formatted for transmission, recorded on compact disc media  
and decoded at conventional video frame rates. During  
10 compression, regions of a frame are individually analyzed to  
select optimum fill coding methods specific to each region.  
Region decoding time estimates are made to optimize  
compression thresholds. Region descriptive codes conveying  
the size and locations of the regions are grouped together in  
15 a first segment of a data stream. Region fill codes  
conveying pixel amplitude indications for the regions are  
grouped together according to fill code type and placed in  
other segments of the data stream. The data stream segments  
are individually variable length coded according to their  
20 respective statistical distributions and formatted to form  
data frames. The number of bytes per frame is withheld by  
the addition of auxiliary data determined by a reverse frame  
sequence analysis to provide an average number selected to  
minimize pauses of the compact disc during playback, thereby  
25 avoiding unpredictable seek mode latency periods  
characteristic of compact discs. A decoder includes a  
variable length decoder responsive to statistical information  
in the code stream for separately variable length decoding  
individual segments of the data stream. Region location data  
30 is derived from region descriptive data and applied with  
region fill codes to a plurality of region specific decoders  
selected by detection of the fill code type (e.g., relative,  
absolute, dyad and DPCM) and decoded region pixels are stored  
in a bit map for subsequent display.

002101 002101 002101

09689120 "101200

United States Patent No. 4,922,341 discloses a method for scene-model-assisted reduction of image data for digital television signals, whereby a picture signal supplied at time is to be coded, whereby a predecessor frame from a scene  
5 already coded at time  $t-1$  is present in an image store as a reference, and whereby the frame-to-frame information is composed of an amplification factor, a shift factor, and an adaptively acquired quad-tree division structure. Upon initialization of the system, a uniform, prescribed gray  
10 scale value or picture half-tone expressed as a defined luminance value is written into the image store of a coder at the transmitter and in the image store of a decoder at the receiver store, in the same way for all picture elements (pixels). Both the image store in the coder as well as the  
15 image store in the decoder are each operated with feed back to themselves in a manner such that the content of the image store in the coder and decoder can be read out in blocks of variable size, can be amplified with a factor greater than or less than 1 of the luminance and can be written back into the  
20 image store with shifted addresses, whereby the blocks of variable size are organized according to a known quad tree data structure.

United States Patent No. 5,122,875 discloses an apparatus for encoding/decoding an HDTV signal. The  
25 apparatus includes a compression circuit responsive to high definition video source signals for providing hierarchically layered codewords CW representing compressed video data and associated codewords T, defining the types of data represented by the codewords CW. A priority selection  
30 circuit, responsive to the codewords CW and T, parses the codewords CW into high and low priority codeword sequences wherein the high and low priority codeword sequences correspond to compressed video data of relatively greater and lesser importance to image reproduction respectively. A

transport processor, responsive to the high and low priority codeword sequences, forms high and low priority transport blocks of high and low priority codewords, respectively. Each transport block includes a header, codewords CW and error detection check bits. The respective transport blocks are applied to a forward error check circuit for applying additional error check data.. Thereafter, the high and low priority data are applied to a modem wherein quadrature amplitude modulates respective carriers for transmission.

10 United States Patent No. 5,146,325 discloses a video decompression system for decompressing compressed image data wherein odd and even fields of the video signal are independently compressed in sequences of intraframe and interframe compression modes and then interleaved for transmission. The odd and even fields are independently decompressed. During intervals when valid decompressed odd/even field data is not available, even/odd field data is substituted for the unavailable odd/even field data. Independently decompressing the even and odd fields of data and substituting the opposite field of data for unavailable data may be used to advantage to reduce image display latency during system start-up and channel changes.

25 United States Patent No. 5,168,356 discloses a video signal encoding system that includes apparatus for segmenting encoded video data into transport blocks for signal transmission. The transport block format enhances signal recovery at the receiver by virtue of providing header data from which a receiver can determine re-entry points into the data stream on the occurrence of a loss or corruption of transmitted data. The re-entry points are maximized by providing secondary transport headers embedded within encoded video data in respective transport blocks.

30 United States Patent No. 5,168,375 discloses a method for processing a field of image data samples to provide for

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one or more of the functions of decimation, interpolation, and sharpening. This is accomplished by an array transform processor such as that employed in a JPEG compression system. Blocks of data samples are transformed by the discrete even cosine transform (DECT) in both the decimation and interpolation processes, after which the number of frequency terms is altered. In the case of decimation, the number of frequency terms is reduced, this being followed by inverse transformation to produce a reduced-size matrix of sample points representing the original block of data. In the case of interpolation, additional frequency components of zero value are inserted into the array of frequency components after which inverse transformation produces an enlarged data sampling set without an increase in spectral bandwidth. In the case of sharpening, accomplished by a convolution or filtering operation involving multiplication of transforms of data and filter kernel in the frequency domain, there is provided an inverse transformation resulting in a set of blocks of processed data samples. The blocks are overlapped followed by a savings of designated samples, and a discarding of excess samples from regions of overlap. The spatial representation of the kernel is modified by reduction of the number of components, for a linear-phase filter, and zero-padded to equal the number of samples of a data block, this being followed by forming the discrete odd cosine transform (DOCT) of the padded kernel matrix.

United States Patent No. 5,175,617 discloses a system and method for transmitting logmap video images through telephone line band-limited analog channels. The pixel organization in the logmap image is designed to match the sensor geometry of the human eye with a greater concentration of pixels at the center. The transmitter divides the frequency band into channels, and assigns one or two pixels to each channel, for example a 3KHz voice quality telephone

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line is divided into 768 channels spaced about 3.9Hz apart. Each channel consists of two carrier waves in quadrature, so each channel can carry two pixels. Some channels are reserved for special calibration signals enabling the receiver to detect both the phase and magnitude of the received signal. If the sensor and pixels are connected directly to a bank of oscillators and the receiver can continuously receive each channel, then the receiver need not be synchronized with the transmitter. An FFT algorithm implements a fast discrete approximation to the continuous case in which the receiver synchronizes to the first frame and then acquires subsequent frames every frame period. The frame period is relatively low compared with the sampling period so the receiver is unlikely to lose frame synchrony once the first frame is detected. An experimental video telephone transmitted 4 frames per second, applied quadrature coding to 1440 pixel logmap images and obtained an effective data transfer rate in excess of 40,000 bits per second.

United States Patent No. 5,185,819 discloses a video compression system having odd and even fields of video signal that are independently compressed in sequences of intraframe and interframe compression modes. The odd and even fields of independently compressed data are interleaved for transmission such that the intraframe even field compressed data occurs midway between successive fields of intraframe odd field compressed data. The interleaved sequence provides receivers with twice the number of entry points into the signal for decoding without increasing the amount of data transmitted.

United States Patent No. 5,212,742 discloses an apparatus and method for processing video data for compression/decompression in real-time. The apparatus comprises a plurality of compute modules, in a preferred embodiment, for a total of four compute modules coupled in

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parallel. Each of the compute modules has a processor, dual port memory, scratch-pad memory, and an arbitration mechanism. A first bus couples the compute modules and host processor. Lastly, the device comprises a shared memory  
5 which is coupled to the host processor and to the compute modules with a second bus. The method handles assigning portions of the image for each of the processors to operate upon.

United States Patent No. 5,231,484 discloses a system  
10 and method for implementing an encoder suitable for use with the proposed ISO/IEC MPEG standards. Included are three cooperating components or subsystems that operate to variously adaptively pre-process the incoming digital motion video sequences, allocate bits to the pictures in a sequence,  
15 and adaptively quantize transform coefficients in different regions of a picture in a video sequence so as to provide optimal visual quality given the number of bits allocated to that picture.

United States Patent No. 5,267,334 discloses a method of  
20 removing frame redundancy in a computer system for a sequence of moving images. The method comprises detecting a first scene change in the sequence of moving images and generating a first keyframe containing complete scene information for a first image. The first keyframe is known, in a preferred  
25 embodiment, as a "forward-facing" keyframe or intraframe, and it is normally present in CCITT compressed video data. The process then comprises generating at least one intermediate compressed frame, the at least one intermediate compressed frame containing difference information from the first image  
30 for at least one image following the first image in time in the sequence of moving images. This at least one frame being known as an interframe. Finally, detecting a second scene change in the sequence of moving images and generating a second keyframe containing complete scene information for an

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image displayed at the time just prior to the second scene change, known as a "backward-facing" keyframe. The first keyframe and the at least one intermediate compressed frame are linked for forward play, and the second keyframe and the intermediate compressed frames are linked in reverse for reverse play. The intraframe may also be used for generation of complete scene information when the images are played in the forward direction. When this sequence is played in reverse, the backward-facing keyframe is used for the generation of complete scene information.

United States Patent No. 5,276,513 discloses a first circuit apparatus, comprising a given number of prior-art image-pyramid stages, together with a second circuit apparatus, comprising the same given number of novel motion-vector stages, perform cost-effective hierarchical motion analysis (HMA) in real-time, with minimum system processing delay and/or employing minimum system processing delay and/or employing minimum hardware structure. Specifically, the first and second circuit apparatus, in response to relatively high-resolution image data from an ongoing input series of successive given pixel-density image-data frames that occur at a relatively high frame rate (e.g., 30 frames per second), derives, after a certain processing-system delay, an ongoing output series of successive given pixel-density vector-data frames that occur at the same given frame rate. Each vector-data frame is indicative of image motion occurring between each pair of successive image frames.

United States Patent No. 5,283,646 discloses a method and apparatus for enabling a real-time video encoding system to accurately deliver the desired number of bits per frame, while coding the image only once, updates the quantization step size used to quantize coefficients which describe, for example, an image to be transmitted over a communications channel. The data is divided into sectors, each sector

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including a plurality of blocks. The blocks are encoded, for example, using DCT coding, to generate a sequence of coefficients for each block. The coefficients can be quantized, and depending upon the quantization step, the number of bits required to describe the data will vary significantly. At the end of the transmission of each sector of data, the accumulated actual number of bits expended is compared with the accumulated desired number of bits expended, for a selected number of sectors associated with the particular group of data. The system then readjusts the quantization step size to target a final desired number of data bits for a plurality of sectors, for example describing an image. Various methods are described for updating the quantization step size and determining desired bit allocations.

The article, Chong, Yong M., A Data-Flow Architecture for Digital Image Processing, Wescon Technical Papers: No. 2 Oct./Nov. 1984, discloses a real-time signal processing system specifically designed for image processing. More particularly, a token based data-flow architecture is disclosed wherein the tokens are of a fixed one word width having a fixed width address field. The system contains a plurality of identical flow processors connected in a ring fashion. The tokens contain a data field, a control field and a tag. The tag field of the token is further broken down into a processor address field and an identifier field. The processor address field is used to direct the tokens to the correct data-flow processor, and the identifier field is used to label the data such that the data-flow processor knows what to do with the data. In this way, the identifier field acts as an instruction for the data-flow processor. The system directs each token to a specific data-flow processor using a module number (MN). If the MN matches the MN of the particular stage, then the appropriate operations are

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The article, Kimori, S. et al. An Elastic Pipeline Mechanism by Self-Timed Circuits, IEEE J. of Solid-State  
5 Circuits, Vol. 23, No. 1, February 1988, discloses an elastic pipeline having self-timed circuits. The asynchronous pipeline comprises a plurality of pipeline stages. Each of the pipeline stages consists of a group of input data latches followed by a combinatorial logic circuit that carries out  
10 logic operations specific to the pipeline stages. The data latches are simultaneously supplied with a triggering signal generated by a data-transfer control circuit associated with that stage. The data-transfer control circuits are interconnected to form a chain through which send and  
15 acknowledge signal lines control a hand-shake mode of data transfer between the successive pipeline stages. Furthermore, a decoder is generally provided in each stage to select operations to be done on the operands in the present stage. It is also possible to locate the decoder in the  
20 preceding stage in order to pre-decode complex decoding processing and to alleviate critical path problems in the logic circuit. The elastic nature of the pipeline eliminates any centralized control since all the interworkings between the submodules are determined by a completely localized  
25 decision and, in addition, each submodule can autonomously perform data buffering and self-timed data-transfer control at the same time. Finally, to increase the elasticity of the pipeline, empty stages are interleaved between the occupied stages in order to ensure reliable data transfer between the  
30 stages.

United States Patent No. 5,278,646 discloses an improved technique for decoding wherein the number of coefficients to be included in each sub-block is selectable, and a code indicating the number of coefficients within each layer is

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inserted in the bitstream at the beginning of each encoded video sequence. This technique allows the original runs of zero coefficients in the highest resolution layer to remain intact by forming a sub-block for each scale from a selected number of coefficients along a continuous scan. These sub-blocks may be decoded in a standard fashion, with an inverse discrete cosine transform applied to square sub-blocks obtained by the appropriate zero padding of and/or discarding of excess coefficients from each of the scales. This technique further improves decoding efficiency by allowing an implicit end of block signal to separate blocks, making it unnecessary to decode an explicit end of block signal in most cases.

United States Patent No. 4,903,018 discloses a process and data processing system for compressing and expanding structurally associated multiple data sequences. The process is particular to data sets in which an analysis is made of the structure in order to identify a characteristic common to a predetermined number of successive data elements of a data sequence. In place of data elements, a code is used which is again decoded during expansion. The common characteristic is obtained by analyzing data elements which have the same order number in a number of data sequences. During expansion, the data elements obtained by decoding the code are ordered in data series on the basis of the order number of these data series on the basis of the order number of these data elements. The data processing system for performing the processes includes a storage matrix (26) and an index storage (28) having line addresses of the storage matrix (26) in an assorted line sequence.

United States Patent No. 4,334,246 discloses a circuit and method for decompressing video subsequent to its prior compression for transmission or storage. The circuit assumes that the original video generated by a raster input scanner

was operated on by a two line one shot predictor, coded using run length encoding into code words of four, eight or twelve bits and packed into sixteen bit data words. This described decompressor, then, unpacks the data by joining together the sixteen bit data words and then separately the individual code words, converts the code words into a number of all zero four bit nibbles and a terminating nibble containing one or more one bits which constitutes decoded data, inspects the actual video of the preceding scan line and the previous video bits of the present line to produce depredictor bits and compares the decoded data and depredictor bits to produce the final actual video.

United States Patent No. 5,060,242 discloses an image signal processing system DPCM encodes the signal, then Huffman and run length encodes the signal to produce variable length code words, which are then tightly packed without gaps for efficient transmission without loss of any data. The tightly packed apparatus has a barrel shifter with its shift modulus controlled by an accumulator receiving code word length information. An OR gate is connected to the shifter, while a register is connected to the gate. Apparatus for processing a tightly packed and decorrelated digital signal has a barrel shifter and accumulator for unpacking, a Huffman and run length decoder, and an inverse DCPM decoder.

United States Patent No. 5,168,375 discloses a method for processing a field of image data samples to provide for one or more of the functions of decimation, interpolation, and sharpening is accomplished by use of an array transform processor such as that employed in a JPEG compression system. Blocks of data samples are transformed by the discrete even cosine transform (DECT) in both the decimation and interpolation processes, after which the number of frequency terms is altered. In the case of decimation, the number of frequency terms is reduced, this being followed by inverse

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transformation to produce a reduced-size matrix of sample points representing the original block of data. In the case of interpolation, additional frequency components of zero value are inserted into the array of frequency components after which inverse transformation produces an enlarged data sampling set without an increase in spectral bandwidth. In the case of sharpening, accomplished by a convolution or filtering operation involving multiplication of transforms of data and filter kernel in the frequency domain, there is provided an inverse transformation resulting in a set of blocks of processed data samples. The blocks are overlapped followed by a savings of designated samples, and a discarding of excess samples from regions of overlap. The spatial representation of the kernel is modified by reduction of the number of components, for a linear-phase filter, and zero-padded to equal the number of samples of a data block, this being followed by forming the discrete odd cosine transform (DOCT) of the padded kernel matrix.

United States Patent No. 5,231,486 discloses a high definition video system processes a bitstream including high and low priority variable length coded Data words. The coded Data is separated into packed High Priority Data and packed Low Priority Data by means of respective data packing units. The coded Data is continuously applied to both packing units. High Priority and Low Priority Length words indicating the bit lengths of high priority and low priority components of the coded Data are applied to the high and low priority data packers, respectively. The Low Priority Length word is zeroed when high Priority Data is to be packed for transport via a first output path, and the High Priority Length word is zeroed when Low Priority Data is to be packed for transport via a second output path.

United States Patent No. 5,287,178 discloses a video signal encoding system includes a signal processor for

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segmenting encoded video data into transport blocks having a header section and a packed data section. The system also includes reset control apparatus for releasing resets of system components, after a global system reset, in a prescribed non-simultaneous phased sequence to enable signal processing to commence in the prescribed sequence. The phased reset release sequence begins when valid data is sensed as transmitting the data lines.

United States Patent No. 5,124,790 to Nakayama discloses a reverse quantizer to be used with image memory. The inverse quantizer is used in the standard way to decode differential predictive coding method (DPCM) encoded data.]

United States Patent No. 5,136,371 to Savatier et al. is directed to a de-quantizer having an adjustable quantizational level which is variable and determined by the fullness of the buffer. The applicants state that the novel aspect of their invention is the maximum available data rate that is achieved. Buffer overflow and underflow is avoided by adapting the quantization step size the quantizer 152 and the de-quantizer 156 by means of a quantizational level which is recalculated after each block has been encoded. The quantization level is calculated as a function of the amount of already encoded data for the frame, compared with the total buffer size. In this manner, the quantization level can advantageously be recalculated by the decoder and does not have to be transmitted.

United States Patent No. 5,142,380 to Sakagami et al. discloses an image compression apparatus suitable for use with still images such as those formed by electronic still cameras using solid state image sensors. The quantizer employed is connected to a memory means from which threshold values of a quantization matrix for the laminate signal, Y, and rom 15 stores threshold values of a quantization matrix for the crominant signals I and Q.

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United States Patent No. 5,193,002 to Guichard et al. disclosed an apparatus for coding/decoding image signals in real time in conjunction with the CCITT standard H.261. A digital signal processor carries out direct quantization and reverse quantization.

United States Patent No. 5,241,383 to Chen et al. describes an apparatus with a pseudo-constant bit rate video coding achieved by an adjustable quantization parameter. The quantization parameter utilized by the quantizer 32 is periodically adjusted to increase or decrease the amount of code bits generated by the coding circuit. The change in quantization parameters for coding the next group of pictures is determined by a deviation measure between the actual number of code bits generated by the coding circuits for the previous group of pictures in an estimate number of code bits for the previous group of pictures. The number of code bits generated by the coding circuit is controlled by controlling the quantizer step sizes. In general smaller quantizer step sizes result in more code bits in larger quantizer step sizes result in fewer code bits.

United States Patent No. 5,113,255 to Nagata et al; 5,126,842 to Andrews et al; 5,253,058 to Gharavi; 5,260,782 to Hui; and 5,212,742 to Normile et al are included for background and as a general description of the art.

Accordingly, those concerned with the design, development and use of video compression/decompression systems and related subsystems have long recognized a need for improved methods and apparatus providing enhanced flexibility, efficiency and performance. The present invention clearly fulfills all these needs.



## SUMMARY OF THE INVENTION

Briefly, and in general terms, the present invention provides an input, an output and a plurality of processing stages between the input and the output, the plurality of processing stages being interconnected by a two-wire interface for conveyance of tokens along a pipeline, and control and/or DATA tokens in the form of universal adaptation units for interfacing with all of the stages in the pipeline and interacting with selected stages in the pipeline for control, data and/or combined control-data functions among the processing stages, whereby the processing stages in the pipeline are afforded enhanced flexibility in configuration and processing.

Each of the processing stages in the pipeline may include both primary and secondary storage, and the stages in the pipeline are reconfigurable in response to recognition of selected tokens. The tokens in the pipeline are dynamically adaptive and may be position dependent upon the processing stages for performance of functions or position independent of the processing stages for performance of functions.

In a pipeline machine, in accordance with the invention, the tokens may be altered by interfacing with the stages, and the tokens may interact with all of the processing stages in the pipeline or only with some but less than all of said processing stages. The tokens in the pipeline may interact with adjacent processing stages or with non-adjacent processing stages, and the tokens may reconfigure the processing stages. Such tokens may be position dependent for some functions and position independent for other functions in the pipeline.

The tokens, in combination with the reconfigurable processing stages, provide a basic building block for the pipeline system. The interaction of the tokens with a processing stage in the pipeline may be conditioned by the previous processing history of that processing stage. The

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5 In an improved pipeline machine, in accordance with the  
invention, the tokens may include an extension bit for each  
token, the extension bit indicating the presence of  
additional words in that token and identifying the last word  
in that token. The address fields may be of variable length  
10 and may also be Huffman coded.

In accordance with the invention, the interactive flexibility of the tokens in cooperation with the processing stages facilitates greater functional diversity of the processing stages for resident structure in the pipeline, and the flexibility of the tokens facilitates system expansion and/or alteration. The tokens may be capable of facilitating a plurality of functions within any processing stage in the pipeline. Such pipeline tokens may be either hardware based or software based. Hence, the tokens facilitate more

efficient uses of system bandwidth in the pipeline. The tokens may provide data and control simultaneously to the processing stages in the pipeline.

5       The invention may include a pipeline processing machine for handling plurality of separately encoded bit streams arranged as a single serial bit stream of digital bits and having separately encoded pairs of control codes and corresponding data carried in the serial bit stream and  
10       employing a plurality of stages interconnected by a two-wire interface, further characterized by a start code detector responsive to the single serial bit stream for generating control tokens and DATA tokens for application to the two-wire interface, a token decode circuit positioned in certain  
15       of the stages for recognizing certain of the tokens as control tokens pertinent to that stage and for passing unrecognized control tokens along the pipeline, and a reconfigurable decode and parser processing means responsive to a recognized control token for reconfiguring a particular  
20       stage to handle an identified DATA token.

      The pipeline machine may also include first and second registers, the first register being positioned as an input of the decode and parser means, with the second register positioned as an output of the decode and parser means. One  
25       of the processing stages may be a spatial decoder, a second of the stages being a token generator for generating control tokens and DATA tokens for passage along the two-wire interface. A token decode means is positioned in the spatial decoder for recognizing certain of the tokens as control  
30       tokens pertinent to the spatial decoder and for configuring the spatial decoder for spatially decoding DATA tokens following a control token into a first decoded format.

      A further stage may be a temporal decoder positioned downstream in the pipeline from the spatial decoder, with a  
35       second token decode means positioned in the temporal decoder

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for recognizing certain of the tokens as control tokens  
pertinent to the temporal decoder and for configuring the  
temporal decoder for temporally decoding the DATA tokens  
5 following the control token into a first decoded format. The  
temporal decoder may utilize a reconfigurable prediction  
filter which is reconfigurable by a prediction token.

Data may be moved along the two-wire interface within  
the temporal decoder in 8x8 pel data blocks, and address  
10 means may be provided for storing and retrieving such data  
blocks along block boundaries. The address means may store  
and retrieve blocks of data across block boundaries. The  
address means reorders said blocks as picture data for  
display. The data blocks stored and retrieved may be greater  
15 and/or smaller than 8x8 pel data blocks. Circuit means may  
also be provided for either displaying the output of the  
temporal decoder or writing the output back into a picture  
memory location. The decoded format may be either a still  
picture format or a moving picture format.

20 The processing stage may also include, in accordance  
with the invention, a token decoder for decoding the address  
of a token and an action identifier responsive to the token  
decoder to implement configuration of the processing stage.  
The processing stages reside in a pipeline processing machine  
25 having a plurality of the processing stages interconnected by  
a two-wire interface bus, with control tokens and DATA tokens  
passing over the two-wire interface. A token decode circuit  
is positioned in certain of the processing stages for  
recognizing certain of the tokens as control tokens pertinent  
30 to that stage and for passing unrecognized control tokens  
along the pipeline. A first input latch circuit may be  
positioned on the two-wire interface preceding the processing  
stage and a second output latch circuit may be positioned on  
the two-wire interface succeeding the processing stage. The  
35 token decode circuit is connected to the two-wire interface

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through the first input latch. Predetermined processing stages may include a decoding circuit connected to the output of a predetermined data storage device, whereby each processing stage assumes the active state only when the stage contains a predetermined stage activation signal pattern and remains in the activation mode until the stage contains a predetermined stage deactivation pattern.

In accordance with the invention, one of the stages is a Start Code Detector for receiving the input and being adapted to generate and/or convert the tokens. The Start Code Detector is responsive to data to create tokens, searches for and detects start codes and produces tokens in response thereto, and is capable of detecting overlapping start codes, whereby the first start code is ignored and the second start code is used to create start code tokens.

The Start Code Detector stage is adapted to search an input data stream in a search mode for a selected start code. The detector searches for breaks in the data stream, and the search may be made of data from an external data source. The Start Code Detector stage may produce a START CODE token, a PICTURE\_START token, a SLICE\_START token, a PICTURE\_END token, a SEQUENCE\_START token, a SEQUENCE\_END token, and/or a GROUP\_START token. The Start Code Detector stage may also perform a padding function by adding bits to the last word of a token.

The Start Code Detector may provide, in a machine for handling a plurality of separately encoded bit streams arranged as a serial bit stream of digital bits and having separately encoded pairs of start codes and data carried in the serial bit stream, a Start Code Detector subsystem having first, second and third registers connected in serial fashion, each of the registers storing a different number of bits from the bit stream, the first register storing a value, the second register and a first decode means identifying a

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start code associated with the value contained in said first register. Circuit means shift the latter value to a predetermined end of the third register, and a second decode means is arranged for accepting data from the third register in parallel.

A memory may also be provided which is responsive to the second decode means for providing one or more control tokens stored in the memory as a result of the decoding of the value associated with the start code. A plurality of tag shift registers may be provided for handling tags indicating the validity of data from the registers. The system may also include means for accessing the input data stream from a microprocessor interface, and means for formatting and organizing the data stream.

In accordance with the invention, the Start Code Detector may identify start codes of varying widths associated with differently encoded bit streams. The detector may generate a plurality of DATA Tokens from the input data stream. Further in accordance with the invention, the system may be a pipeline system and the Start Code Detector may be positioned as the first processing stage in the pipeline.

The present invention also provides, in a digital picture information processing system, means for selectively configuring the system to process data in accordance with a plurality of different picture compression/decompression standards. The picture standards may include JPEG, MPEG, and/or H.261, or any other standards and any combination of such picture standards, without departing in any way from the spirit and scope of the invention. In accordance with the invention, the system may include a spatial decoder for video data and having a Huffman decoder, an index to data and an arithmetic logic unit with a microcode ROM having separate stored programs for each of a plurality of different picture

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conditioning the system for processing in a selected one of a plurality of picture compression/decompression standards.

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standard. At least some of the processing stages reconfigure in response to the CODING\_STANDARD token.

One of the processing stages in the system may be a Huffman decoder and parser and, upon receipt of a CODING\_STANDARD control token, the parser is reset to an address location corresponding to the location of a program for handling the picture standard identified by the CODING\_STANDARD control token. A reset address may also be selected by the CODING\_STANDARD control token corresponding to a memory location used for testing the Huffman decoder and parser.

The Huffman decoder may include a decoding stage and an Index to Data stage, and the parser stage may send an instruction to the Index to Data Unit to select tables needed for a particular identified coding standard, the parser stage indicating whether the arriving data is inverted or not.

The aforescribed tokens may take the form of an interactive metamorphic interfacing token.

The present invention also provides a system for decoding video data, having a Huffman decoder, an index to data (ITOD) stage, an arithmetic logic unit (ALU), and a data buffering means immediately following the system, whereby time spread for video pictures of varying data size can be controlled.

The system may include a spatial decoder having a two-wire interface interconnecting processing stages, the interface enabling serial processing for data and parallel processing for control.

As previously indicated, the system may further include a ROM having separate stored programs for each of a plurality of picture standards, the programs being selectable by a token to facilitate processing for a plurality of different picture standards.

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The spatial decoder system also includes a token formatter for formatting tokens, so that DATA tokens are created.

5       The system may also include a decoding stage and a parser stage for sending an instruction to the Index to Data Unit to select tables needed for a particular identified coding standard, the parser stage indicating whether the arriving data is inverted or not. The tables may be arranged  
10       within a memory for enabling multiple use of the tables where appropriate.

      The present invention also provides a pipeline system having an input data stream, and a processing stage for receiving the input data stream, the stage including means  
15       for recognizing specified bit stream patterns, whereby said stage facilitates random access and error recovery. In accordance with the invention, the processing stage may be a start code detector and the bit stream patterns may include start codes. Hence, the invention provides a search-mode  
20       means for searching differently encoded data streams arranged as a single serial stream of data for allowing random access and enhanced error recovery.

      The present invention also provides a pipeline machine having means for performing a stop-after-picture operation  
25       for achieving a clear end to picture data decoding, for indicating the end of a picture, and for clearing the pipeline, wherein such means generates a combination of a PICTURE\_END token and a FLUSH token.

      The present invention also provides, in a pipeline  
30       machine, a fixed size, fixed width buffer and means for padding the buffer to pass an arbitrary number of bits through the buffer. The padding means may be a start code detector.

      Padding may be performed only on the last word of a  
35       token and padding insures uniformity of word size. In

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accordance with the invention, a reconfigurable processing stage may be provided as a spatial decoder and the padding means adds to picture data being handled by the spatial decoder sufficient additional bits such that each decompressed picture at the output of the spatial decoder is of the same length in bits.

The present invention also provides, in a system having a data stream including run length code, an inverse modeller means active upon the data stream from a token for expanding out the run level code to a run of zero data followed by a level, whereby each token is expressed with a specified number of values. The token may be a DATA token.

The inverse modeller means blocks tokens which lack the specified number of values, and the specified number of values may be 64 coefficients in a presently preferred embodiment of the invention.

The practice of the invention may include an expanding circuit for accepting a DATA token having run length codes and decoding the run length codes. A padder circuit in communication with the expanding circuit checks that the DATA token has a predetermined length so that if the DATA token has less than the predetermined length, the padder circuit adds units of data to the DATA token until the predetermined length is achieved. A bypass circuit is also provided for bypassing any token other than a DATA token around the expanding circuit and the padding circuit.

In accordance with the invention, a method is provided for data to efficiently fill a buffer, including providing first type tokens having a first predetermined width, and at least one of the following formats:

Format A - ExxxxxxLLLLLLLLLLLL

Format B - ERRRRRLLLLLLLLLLLL

Format C - E000000LLLLLLLLLLLL

where E=extension bit; F=specifics format; R=run bit;

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L=length bit or non-data token; x="don't care" bit, splitting format A tokens into a format 0a token having a form of ELLLLLLLLLLLLL, splitting format B tokens into a format 1 token  
5 having the form of FRRRRRRR00000 and a format 0a data token, splitting format C tokens into a format 0 token having the form of FLLLLLLLLLLLLL, and packing format 0, format 0a and format 1 tokens into a buffer, having a second predetermined width.

10 The invention also provides an apparatus for providing a time delay to a group of compressed pictures, the pictures corresponding to a video compression/ decompression standard, wherein words of data containing compressed pictures are counted by a counter circuit and a microprocessor, in  
15 communication with the counter circuit and adapted to receive start-up information consistent with the standard of video decompression, communicates the start-up information to the counter circuit.

An inverse modeller circuit, for accepting the words of  
20 data and capable of delaying the words of data, is in communication with a control circuit intermediate the counter circuit and the inverse modeller circuit, the control circuit also communicating with the counter circuit which compares the start-up information with the counted words of data and  
25 signals the control circuit. The control circuit queues the signals in correspondence to the words of data that have met the start-up criterion and controls the inverse modeller delay feature. .

The present invention also provides in a pipeline system  
30 having an inverse modeller stage and an inverse discrete cosine transform stage, the improvement characterized by a processing stage, positioned between the inverse modeller stage and the inverse discrete cosine transform stage, responsive to a token table for processing data.

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In accordance with the invention, the token may be a QUANT\_TABLE token for causing the processing stage to generate a quantization table.

5       The present invention also provides a Huffman decoder for decoding data words encoded according to the Huffman coding provisions of either H.261, JPEG or MPEG standards, the data words including an identifier that identifies the Huffman code standard under which the data words were coded, and comprising means for receiving the Huffman coded data words, means for reading the identifier to determine which standard governed the Huffman coding of the received data words, means for converting the data words to JPEG Huffman coded data words, if necessary, in response to reading the identifier that identifies the Huffman coded data words as H.261 or MPEG Huffman coded, means operably connected to the Huffman coded data words receiving means for generating an index number associated with each JPEG Huffman coded data word received from the Huffman coded data words receiving means, and means for operating a lookup table containing a Huffman code table having the format used under the JPEG standard to transmit JPEG Huffman table information, including an input for receiving an index number from the index number generating means, and including an output that is a decoded data word corresponding to the index number.

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The invention further relates, in varying degrees of scope, to a method for decoding data words encoded according to the Huffman coding provisions of either H.261, JPEG or MPEG standards, the data words including an identifier that identifies the Huffman code standard under which the data words were coded, such steps comprising receiving the Huffman coded data words, including reading the identifier to determine which standard governed the Huffman coding of the received data words, if necessary, in response to reading the identifier that identifies the Huffman coded data words as

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H.261 or MPEG Huffman coded, generating an index number associated with each JPEG Huffman coded data word received, operating a lookup table containing a Huffman code table  
5 having the format used under the JPEG standard to transmit JPEG Huffman table information, including receiving an index number, and generating a decoded data word corresponding to the received index number.

The above and other objectives and advantages of the  
10 invention will become apparent from the following more detailed description when taken in conjunction with the accompanying drawings.

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## DESCRIPTION OF THE DRAWINGS

Figure. 1 illustrates six cycles of a six-stage pipeline for different combinations of two internal control signals;

5 Figures. 2a and 2b illustrate a pipeline in which each stage includes auxiliary data storage. They also show the manner in which pipeline stages can "compress" and "expand" in response to delays in the pipeline;

Figures. 3a(1), 3a(2), 3b(1) and 3b(2) illustrate the control  
10 of data transfer between stages of a preferred embodiment of  
a pipeline using a two-wire interface and a multi-phase  
clock;

Figure. 4 is a block diagram that illustrates a basic embodiment of a pipeline stage that incorporates a two-wire transfer control and also shows two consecutive pipeline processing stages with the two-wire transfer control;

Figures. 5a and 5b taken together depict one example of a timing diagram that shows the relationship between timing signals, input and output data, and internal control signals used in the pipeline stage as shown in Figure. 4;

Figure. 6 is a block diagram of one example of a pipeline stage that holds its state under the control of an extension bit;

Figure. 7 is a block diagram of a pipeline stage that decodes  
25 stage activation data words;

Figures. 8a and 8b taken together form a block diagram showing the use of the two-wire transfer control in an exemplifying "data duplication" pipeline stage;

Figures. 9a and 9b taken together depict one example of a timing diagram that shows the two-phase clock, the two-wire transfer control signals and the other internal data and control signals used in the exemplifying embodiment shown in Figures. 8a and 8b.

Figure 10 is a block diagram of a reconfigurable processing  
35 stage;

Figure 11 is a block diagram of a spatial decoder;  
Figure 12 is a block diagram of a temporal decoder;  
Figure 13 is a block diagram of a video formatter;

5 Figures 14a-c show various arrangements of memory blocks used  
in the present invention:

Figure 14a is a memory map showing a first  
arrangement of macroblocks;

10 Figure 14b is a memory map showing a second  
arrangement of macroblocks;

Figure 14c is a memory map showing a further  
arrangement of macroblocks;

Figure 15 shows a Venn diagram of possible table selection  
values;

15 Figure 16 shows the variable length of picture data used in  
the present invention;

Figure 17 is a block diagram of the temporal decoder  
including the prediction filters;

20 Figure 18 is a pictorial representation of the prediction  
filtering process;

Figure 19 shows a generalized representation of the  
macroblock structure;

Figure 20 shows a generalized block diagram of a Start Code  
Detector;

25 Figure 21 illustrates examples of start codes in a data  
stream;

Figure 22 is a block diagram depicting the relationship  
between the flag generator, decode index, header  
generator, extra word generator and output latches;

30 Figure 23 is a block diagram of the Spatial Decoder DRAM  
interface;

Figure 24 is a block diagram of a write swing buffer;

Figure 25 is a pictorial diagram illustrating prediction data  
offset from the block being processed;

35 Figure 26 is a pictorial diagram illustrating prediction data

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offset by (1,1);

Figure 27 is a block diagram illustrating the Huffman decoder and parser state machine of the Spatial Decoder.

- 5 Figure 28 is a block diagram illustrating the prediction filter.

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## FIGURES

	Figure 29	shows a typical decoder system;
	Figure 30	shows a JPEG still picture decoder;
5	Figure 31	shows a JPEG video decoder;
	Figure 32	shows a multi-standard video decoder;
	Figure 33	shows the start and the end of a token;
	Figure 34	shows a token address and data fields;
	Figure 35	shows a token on an interface wider than
10	8 bits;	
	Figure 36	shows a macroblock structure;
	Figure 37	shows a two-wire interface protocol;
	Figure 38	shows the location of external two-wire
	interfaces;	
15	Figure 39	shows clock propagation;
	Figure 40	shows two-wire interface timing;
	Figure 41	shows examples of access structure;
	Figure 42	shows a read transfer cycle;
	Figure 43	shows an access start timing;
20	Figure 44	shows an example access with two write
	transfers;	
	Figure 45	shows a read transfer cycle;
	Figure 46	shows a write transfer cycle;
	Figure 47	shows a refresh cycle;
25	Figure 48	shows a 32 bit data bus and a 256 kbit
	deep DRAMs (9 bit row address);	
	Figure 49	shows timing parameters for any strobe
	signal;	
	Figure 50	shows timing parameters between any two
30	strobe signals;	
	Figure 51	shows timing parameters between a bus and
	a strobe;	
	Figure 52	shows timing parameters between a bus and
	a strobe;	
35	Figure 53	shows an MPI read timing;
	Figure 54	shows an MPI write timing;
	Figure 55	shows organization of large integers in
	the memory map;	
	Figure 56	shows a typical decoder clock regime;
40	Figure 57	shows input clock requirements;
	Figure 58	shows the Spatial Decoder;
	Figure 59	shows the inputs and outputs of the input
	circuit;	
	Figure 60	shows the coded port protocol;
45	Figure 61	shows the start code detector;
	Figure 62	shows start codes detected and converted
	to Tokens;	
	Figure 63	shows the start codes detector passing
	Tokens;	
50	Figure 64	shows overlapping MPEG start codes (byte
	aligned);	
	Figure 65	shows overlapping MPEG start codes (not

	byte aligned);	
	Figure 66	shows jumping between two video
	sequences;	
5	Figure 67	shows a sequence of extra Token
	insertion;	
	Figure 68	shows decoder start-up control;
	Figure 69	shows enabled streams queued before the
	output;	
10	Figure 70	shows a spatial decoder buffer;
	Figure 71	shows a buffer pointer;
	Figure 72	shows a video demux;
	Figure 73	shows a construction of a picture;
	Figure 74	shows a construction of a 4:2:2
15	macroblock;	
	Figure 75	shows a calculating macroblock dimension
	from pel ones;	
	Figure 76	shows spatial decoding;
	Figure 77	shows an overview of H.261 inverse
20	quantization;	
	Figure 78	shows an overview of JPEG inverse
	quantization;	
	Figure 79	shows an overview of MPEG inverse
	quantization;	
25	Figure 80	shows a quantization table memory map;
	Figure 81	shows an overview of JPEG baseline
	sequential structure;	
	Figure 82	shows a tokenised JPEG picture;
	Figure 83	shows a temporal decoder;
30	Figure 84	shows a picture buffer specification;
	Figure 85	shows an MPEG picture sequence (m=3);
	Figure 86	shows how "I" pictures are stored and
	output;	
	Figure 87	shows how "P" pictures are formed, stored
35	and output;	
	Figure 88	shows how "B" pictures are formed and
	output;	
	Figure 89	shows P picture formation;
	Figure 90	shows H.261 prediction formation;
40	Figure 91	shows an H.261 "sequence";
	Figure 92	shows a hierarchy of H.261 syntax;
	Figure 93	shows an H.261 picture layer;
	Figure 94	shows an H.261 arrangement of groups of
	blocks;	
45	Figure 95	shows an H.261 "slice" layer;
	Figure 96	shows an H.261 arrangement of
	macroblocks;	
	Figure 97	shows an H.261 sequence of blocks;
	Figure 98	shows an H.261 macroblock layer;
50	Figure 99	shows an H.261 arrangement of pels in
	blocks;	
	Figure 100	shows a hierarchy of MPEG syntax;
	Figure 101	shows an MPEG sequence layer;

	Figure 102	shows an MPEG group of pictures layer;
	Figure 103	shows an MPEG picture layer;
	Figure 104	shows an MPEG "slice" layer;
5	Figure 105	shows an MPEG sequence of blocks;
	Figure 106	shows an MPEG macroblock layer;
	Figure 107	shows an "open GOP";
	Figure 108	shows examples of access structure;
	Figure 109	shows access start timing;
10	Figure 110	shows a fast page read cycle;
	Figure 111	shows a fast page write cycle;
	Figure 112	shows a refresh cycle;
	Figure 113	shows extracting row and column address from a chip address;
15	Figure 114	shows timing parameters for any strobe signal;
	Figure 115	shows timing parameters between any two strobe signals;
	Figure 116	shows timing parameters between a bus and a strobe;
20	Figure 117	shows timing parameters between a bus and a strobe;
	Figure 118	shows a Huffman decoder and parser;
	Figure 119	shows an H.261 and an MPEG AC Coefficient
25	Decoding Flow Chart;	
	Figure 120	shows a block diagram for JPEG (AC and DC) coefficient decoding;
	Figure 121	shows a flow diagram for JPEG (AC and DC) coefficient decoding;
30	Figure 122	shows an interface to the Huffman Token Formatter;
	Figure 123	shows a token formatter block diagram;
	Figure 124	shows an H.261 and an MPEG AC Coefficient Decoding;
35	Figure 125	shows the interface to the Huffman ALU;
	Figure 126	shows the basic structure of the Huffman ALU;
	Figure 127	shows the buffer manager;
	Figure 128	shows an imodel and hspk block diagram;
40	Figure 129	shows an imex state diagram;
	Figure 130	illustrates the buffer start-up;
	Figure 131	shows a DRAM interface;
	Figure 132	shows a write swing buffer;
	Figure 133	shows an arithmetic block;
45	Figure 134	shows an iq block diagram;
	Figure 135	shows an iqca state machine;
	Figure 136	shows an IDCT 1-D Transform Algorithm;
	Figure 137	shows an IDCT 1-D Transform Architecture;
	Figure 138	shows a token stream block diagram;
50	Figure 139	shows a standard block structure;
	Figure 140	is a block diagram showing;
	microprocessor test access;	
	Figure 141	shows 1-D Transform Micro-Architecture;

	Figure 142	shows a temporal decoder block diagram;
	Figure 143	shows the structure of a Two-wire
	interface stage;	
5	Figure 144	shows the address generator block
	diagram;	
	Figure 145	shows the block and pixel offsets;
	Figure 146	shows multiple prediction filters;
	Figure 147	shows a single prediction filter;
10	Figure 148	shows the 1-D prediction filter;
	Figure 149	shows a block of pixels;
	Figure 150	shows the structure of the read rudder;
	Figure 151	shows the block and pixel offsets;
	Figure 152	shows a prediction example;
15	Figure 153	shows the read cycle;
	Figure 154	shows the write cycle;
	Figure 155	shows the top-level registers block
	diagram with timing	references;
20	Figure 156	shows the control for incrementing
	presentation numbers;	
	Figure 157	shows the buffer manager state machine
	(complete);	
	Figure 158	shows the state machine main loop;
	Figure 159	shows the buffer 0 containing an SIF (22
25	by 18 macroblocks) picture;	
	Figure 160	shows the SIF component 0 with a display
	window;	
	Figure 161	shows an example picture format showing
	storage block address;	
30	Figure 162	shows a buffer 0 containing a SIF (22 by
	18 macroblocks) picture;	
	Figure 163	shows an example address calculation;
	Figure 164	shows a write address generation state
	machine;	
35	Figure 165	shows a slice of the datapath;
	Figure 166	shows a two cycle operation of the
	datapath;	
	Figure 167	shows mode 1 filtering;
	Figure 168	shows a horizontal up-sampler datapath;
40	and	
	Figure 169	shows the structure of the color-space
	converter.	

In the ensuing description of the practice of the invention, the following terms are frequently used and are generally defined by the following glossary:

5

**GLOSSARY**

**BLOCK:** An 8-row by 8-column matrix of pels, or 64 DCT coefficients (source, quantized or dequantized).

**CHROMINANCE (COMPONENT):** A matrix, block or single pel representing one of the two color difference signals related to the primary colors in the manner defined in the bit stream. The symbols used for the color difference signals are Cr and Cb.

**CODED REPRESENTATION:** A data element as represented in its encoded form.

**CODED VIDEO BIT STREAM:** A coded representation of a series of one or more pictures as defined in this specification.

**CODED ORDER:** The order in which the pictures are transmitted and decoded. This order is not necessarily the same as the display order.

**COMPONENT:** A matrix, block or single pel from one of the three matrices (luminance and two chrominance) that make up a picture.

**COMPRESSION:** Reduction in the number of bits used to represent an item of data.

**DECODER:** An embodiment of a decoding process.

**DECODING (PROCESS):** The process defined in this specification that reads an input coded bitstream and produces decoded pictures or audio samples.

**DISPLAY ORDER:** The order in which the decoded pictures are displayed. Typically, this is the same order in which they were presented at the input of the encoder.

**ENCODING (PROCESS):** A process, not specified in this specification, that reads a stream of input pictures or audio samples and produces a valid coded bitstream as defined in this specification.

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**INTRA CODING:** Coding of a macroblock or picture that uses information only from that macroblock or picture.

5 **LUMINANCE (COMPONENT):** A matrix, block or single pel representing a monochrome representation of the signal and related to the primary colors in the manner defined in the bit stream. The symbol used for luminance is Y.

10 **MACROBLOCK:** The four 8 by 8 blocks of luminance data and the two (for 4:2:0 chroma format) four (for 4:2:2 chroma format) or eight (for 4:4:4 chroma format) corresponding 8 by 8 blocks of chrominance data coming from a 16 by 16 section of the luminance component of the picture. Macroblock is sometimes used to refer to the pel data and sometimes to the coded representation of the pel values and other data  
15 elements defined in the macroblock header of the syntax defined in this part of this specification. To one of ordinary skill in the art, the usage is clear from the context.

20 **MOTION COMPENSATION:** The use of motion vectors to improve the efficiency of the prediction of pel values. The prediction uses motion vectors to provide offsets into the past and/or future reference pictures containing previously decoded pel values that are used to form the prediction error signal.

25 **MOTION VECTOR:** A two-dimensional vector used for motion compensation that provides an offset from the coordinate position in the current picture to the coordinates in a reference picture.

30 **NON-INTRA CODING:** Coding of a macroblock or picture that uses information both from itself and from macroblocks and pictures occurring at other times.

**PEL:** Picture element.

35 **PICTURE:** Source, coded or reconstructed image data. A source or reconstructed picture consists of three rectangular matrices of 8-bit numbers representing the luminance and two chrominance signals. For progressive video, a picture is

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identical to a frame, while for interlaced video, a picture can refer to a frame, or the top field or the bottom field of the frame depending on the context.

5 **PREDICTION:** The use of a predictor to provide an estimate of the pel value or data element currently being decoded.

**RECONFIGURABLE PROCESS STAGE (RPS):** A stage, which in response to a recognized token, reconfigures itself to perform various operations.

10 **SLICE:** A series of macroblocks.

**TOKEN:** A universal adaptation unit in the form of an interactive interfacing messenger package for control and/or data functions.

**START CODES [SYSTEM AND VIDEO]:** 32-bit codes embedded in a coded bitstream that are unique. They are used for several purposes including identifying some of the structures in the coding syntax.

15 **VARIABLE LENGTH CODING; VLC:** A reversible procedure for coding that assigns shorter code-words to frequent events and longer code-words to less frequent events.

20 **VIDEO SEQUENCE:** A series of one or more pictures.

Detailed Descriptions

## DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

As an introduction to the most general features used in a pipeline system which is utilized in the preferred  
5 embodiments of the invention, Fig. 1 is a greatly simplified illustration of six cycles of a six-stage pipeline. (As is explained in greater detail below, the preferred embodiment of the pipeline includes several advantageous features not shown in Fig 1.).

10 Referring now to the drawings, wherein like reference numerals denote like or corresponding elements throughout the various figures of the drawings, and more particularly to Fig. 1, there is shown a block diagram of six cycles in practice of the present invention. Each row of boxes  
15 illustrates a cycle and each of the different stages are labelled A-F, respectively. Each shaded box indicates that the corresponding stage holds valid data, i.e., data that is to be processed in one of the pipeline stages. After processing (which may involve nothing more than a simple transfer without manipulation of the data) valid data is  
20 transferred out of the pipeline as valid output data.

Note that an actual pipeline application may include more or fewer than six pipeline stages. As will be appreciated, the present invention may be used with any number of pipeline  
25 stages. Furthermore, data may be processed in more than one stage and the processing time for different stages can differ.

In addition to clock and data signals (described below), the pipeline includes two transfer control signals -- a  
30 "VALID" signal and an "ACCEPT" signal. These signals are used to control the transfer of data within the pipeline. The VALID signal, which is illustrated as the upper of the two lines connecting neighboring stages, is passed in a forward or downstream direction from each pipeline stage to  
35 the nearest neighboring device. This device may be another

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Although not shown in Fig. 1, there are data lines, either single lines or several parallel lines, which form a data bus that also lead into and out of each pipeline stage. As is explained and illustrated in greater detail below, data is transferred into, out of, and between the stages of the pipeline over the data lines.

When a pipeline stage contains valid data that is to be transferred down the pipeline, the VALID signal, which indicates data validity, need not be transferred further than to the immediately subsequent pipeline stage. A two-wire interface is, therefore, included between every pair of pipeline stages in the system. This includes a two-wire interface between a preceding device and the first stage, and between a subsequent device and the last stage, if such other devices are included and data is to be transferred between them and the pipeline.

20 Each of the signals, ACCEPT and VALID, has a HIGH and a LOW value. These values are abbreviated as "H" and "L", respectively. The most common applications of the pipeline, in practicing the invention, will typically be digital. In such digital implementations, the HIGH value may, for

example, be a logical "1" and the LOW value may be a logical "0". The system is not restricted to digital implementations, however, and in analog implementations, the HIGH value may be a voltage or other similar quantity above (or below) a set threshold, with the LOW value being indicated by the corresponding signal being below (or above) the same or some other threshold. For digital applications, the present invention may be implemented using any known technology, such as CMOS, bipolar etc.

It is not necessary to use a distinct storage device and wires to provide for storage of VALID signals. This is true even in a digital embodiment. All that is required is that the indication of "validity" of the data be stored along with the data. By way of example only, in digital television pictures that are represented by digital values, as specified in the international standard CCIR 601, certain specific values are not allowed. In this system, eight-bit binary numbers are used to represent samples of the picture and the values zero and 255 may not be used.

If such a picture were to be processed in a pipeline built in the practice of the present invention, then one of these values (zero, for example) could be used to indicate that the data in a specific stage in the pipeline is not valid. Accordingly, any non-zero data would be deemed to be valid. In this example, there is no specific latch that can be identified and said to be storing the "validness" of the associated data. Nonetheless, the validity of the data is stored along with the data.

As shown in Fig. 1, the state of the VALID signal into each stage is indicated as an "H" or an "L" on an upper, right-pointed arrow. Therefore, the VALID signal from Stage A into Stage B is LOW, and the VALID signal from Stage D into Stage E is HIGH. The state of the ACCEPT signal into each stage is indicated as an "H" or an "L" on a lower, left-

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into their respective following devices is HIGH. The VALID signal from the Stages A, C and F is, however, LOW since these stages do not contain valid data.

Assume now that the device connected downstream from the pipeline is not ready to accept data from the pipeline. The device signals this by setting the corresponding ACCEPT signal LOW into Stage F. Stage F itself, however, does not contain valid data and is, therefore, able to accept data from the preceding Stage E. Hence, the ACCEPT signal from Stage F into Stage E is set HIGH.

Similarly, Stage E contains valid data and Stage F is ready to accept this data. Hence, Stage E can accept new data as long as the valid data D1 is first transferred to Stage F. In other words, although Stage F cannot transfer data downstream, all the other stages can do so without any valid data being overwritten or lost. At the end of Cycle 1, data can, therefore, be "shifted" one step to the right. This condition is shown in Cycle 2.

In the illustrated example, the downstream device is still not ready to accept new data in Cycle 2 and, therefore, the ACCEPT signal into Stage F is still LOW. Stage F cannot, therefore, accept new data since doing so would cause valid data D1 to be overwritten and lost. The ACCEPT signal from Stage F into Stage E, therefore, goes LOW, as does the ACCEPT signal from Stage E into Stage D since Stage E also contains valid data D2. All of the Stages A-D, however, are able to accept new data (either because they do not contain valid data or because they are able to shift their valid data downstream and accept new data) and they signal this condition to their immediately preceding neighbors by setting their corresponding ACCEPT signals HIGH.

The state of the pipelines after Cycle 2 is illustrated in Fig. 1 for the row labelled Cycle 3. By way of example, it is assumed that the downstream device is still not ready to

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accept new data from Stage F (the ACCEPT signal into Stage F is LOW). Stages E and F, therefore, are still "blocked", but in Cycle 3, Stage D has received the valid data D3, which has overwritten the invalid data that was previously in this stage. Since Stage D cannot pass on data D3 in Cycle 3, it cannot accept new data and, therefore, sets the ACCEPT signal into Stage C LOW. However, stages A-C are ready to accept new data and signal this by setting their corresponding ACCEPT signals HIGH. Note that data D4 has been shifted from Stage A to Stage B.

Assume now that the downstream device becomes ready to accept new data in Cycle 4. It signals this to the pipeline by setting the ACCEPT signal into Stage F HIGH. Although Stages C-F contain valid data, they can now shift the data downstream and are, thus, able to accept new data. Since each stage is therefore able to shift data one step downstream, they set their respective ACCEPT signals out HIGH.

As long as the ACCEPT signal into the final pipeline stage (in this example, Stage F) is HIGH, the pipeline shown in Fig. 1 acts as a rigid pipeline and simply shifts data one step downstream on each cycle. Accordingly, in Cycle 5, data D1, which was contained in Stage F in Cycle 4, is shifted out of the pipeline to the subsequent device, and all other data is shifted one step downstream.

Assume now, that the ACCEPT signal into Stage F goes LOW in Cycle 5. Once again, this means that Stages D-F are not able to accept new data, and the ACCEPT signals out of these stages into their immediately preceding neighbors go LOW. Hence, the data D2, D3 and D4 cannot shift downstream, however, the data D5 can. The corresponding state of the pipeline after Cycle 5 is, thus, shown in Fig. 1 as Cycle 6.

The ability of the pipeline, in accordance with the preferred embodiments of the present invention, to "fill up"

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empty processing stages is highly advantageous since the processing stages in the pipeline thereby become decouple from one another. In other words, even though a pipeline stage may not be ready to accept data, the entire pipeline does not have to stop and wait for the delayed stage. Rather, when one stage is unable to accept valid data it simply forms a temporary "wall" in the pipeline. Nonetheless, stages downstream of the "wall" can continue to advance valid data even to circuitry connected to the pipeline, and stages to the left of the "wall" can still accept and transfer valid data downstream. Even when several pipeline stages temporarily cannot accept new data, other stages can continue to operate normally. In particular, the pipeline can continue to accept data into its initial stage A as long as stage A does not already contain valid data that cannot be advanced due to the next stage not being ready to accept new data. As this example illustrates, data can be transferred into the pipeline and between stages even when one or more processing stages is blocked.

In the embodiment shown in Fig. 1, it is assumed that the various pipeline stages do not store the ACCEPT signals they receive from their immediately following neighbors. Instead, whenever the ACCEPT signal into a downstream stage goes LOW, this LOW signal is propagated upstream as far as the nearest pipeline stage that does not contain valid data. For example, referring to Fig. 1, it was assumed that the ACCEPT signal into Stage F goes LOW in Cycle 1. In Cycle 2, the LOW signal propagates from Stage F back to Stage D.

In Cycle 3, when the data D3 is latched into Stage D, the ACCEPT signal propagates upstream four stages to Stage C. When the ACCEPT signal into Stage F goes HIGH in Cycle 4, it must propagate upstream all the way to Stage C. In other words, the change in the ACCEPT signal must propagate back four stages. It is not necessary, however, in the embodiment

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illustrated in Fig. 1, for the ACCEPT signal to propagate all the way back to the beginning of the pipeline if there is some intermediate stage that is able to accept new data.

In the embodiment illustrated in Fig. 1, each pipeline stage will still need separate input and output data latches to allow data to be transferred between stages without unintended overwriting. Also, although the pipeline illustrated in Fig. 1 is able to "compress" when downstream pipeline stages are blocked, i.e., they cannot pass on the data they contain, the pipeline does not "expand" to provide stages that contain no valid data between stages that do contain valid data. Rather, the ability to compress depends on there being cycles during which no valid data is presented to the first pipeline stage.

In Cycle 4, for example, if the ACCEPT signal into Stage F remained LOW and valid data filled pipeline stages A and B, as long as valid data continued to be presented to Stage A the pipeline would not be able to compress any further and valid input data could be lost. Nonetheless, the pipeline illustrated in Fig. 1 reduces the risk of data loss since it is able to compress as long as there is a pipeline stage that does not contain valid data.

Fig. 2 illustrates another embodiment of the pipeline that can both compress and expand in a logical manner and which includes circuitry that limits propagation of the ACCEPT signal to the nearest preceding stage. Although the circuitry for implementing this embodiment is explained and illustrated in greater detail below, Fig. 2 serves to illustrate the principle by which it operates.

For ease of comparison only, the input data and ACCEPT signals into the pipeline embodiment shown in Fig. 2 are the same as in the pipeline embodiment shown in Fig. 1. Accordingly, stages E, D and B contain valid data D1, D2 and D3, respectively. The ACCEPT signal into Stage F is LOW; and

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data D4 is presented to the beginning pipeline Stage A. In Fig. 2, three lines are shown connecting each neighboring pair of pipeline stages. The uppermost line, which may be a bus, is a data line. The middle line is the line over which the VALID signal is transferred, while the bottom line is the line over which the ACCEPT signal is transferred. Also, as before, the ACCEPT signal into Stage F remains LOW except in Cycle 4. Furthermore, additional data D5 is presented to the pipeline in Cycle 4.

In Fig. 2, each pipeline stage is represented as a block divided into two halves to illustrate that each stage in this embodiment of the pipeline includes primary and secondary data storage elements. In Fig. 2, the primary data storage is shown as the right half of each stage. However, it will be appreciated that this delineation is for the purpose of illustration only and is not intended as a limitation.

As Fig. 2 illustrates, as long as the ACCEPT signal into a stage is HIGH, data is transferred from the primary storage elements of the stage to the secondary storage elements of the following stage during any given cycle. Accordingly, although the ACCEPT signal into Stage F is LOW, the ACCEPT signal into all other stages is HIGH so that the data D1, D2 and D3 is shifted forward one stage in Cycle 2 and the data D4 is shifted into the first Stage A.

Up to this point, the pipeline embodiment shown in Fig. 2 acts in a manner similar to the pipeline embodiment shown in Fig. 1. The ACCEPT signal from Stage F into Stage E, however, is HIGH even though the ACCEPT signal into Stage F is LOW. As is explained below, because of the secondary storage elements, it is not necessary for the LOW ACCEPT signal to propagate upstream beyond Stage F. Moreover, by leaving the ACCEPT signal into Stage E HIGH, Stage F signals that it is ready to accept new data. Since Stage F is not able to transfer the data D1 in its primary storage elements

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downstream (the ACCEPT signal into Stage F is LOW) in Cycle 3, Stage E must, therefore, transfer the data D2 into the secondary storage elements of Stage F. Since both the primary and the secondary storage elements of Stage F now contain valid data that cannot be passed on, the ACCEPT signal from Stage F into Stage E is set LOW. Accordingly, this represents a propagation of the LOW ACCEPT signal back only one stage relative to Cycle 2, whereas this ACCEPT signal had to be propagated back all the way to Stage C in the embodiment shown in Fig. 1.

Since Stages A-E are able to pass on their data, the ACCEPT signals from the stages into their immediately preceding neighbors are set HIGH. Consequently, the data D3 and D4 are shifted one stage to the right so that, in Cycle 4, they are loaded into the primary data storage elements of Stage E and Stage C, respectively. Although Stage E now contains valid data D3 in its primary storage elements, its secondary storage elements can still be used to store other data without risk of overwriting any valid data.

Assume now, as before, that the ACCEPT signal into Stage F becomes HIGH in Cycle 4. This indicates that the downstream device to which the pipeline passes data is ready to accept data from the pipeline. Stage F, however, has set its ACCEPT signal LOW and, thus, indicates to Stage E that Stage F is not prepared to accept new data. Observe that the ACCEPT signals for each cycle indicate what will "happen" in the next cycle, that is, whether data will be passed on (ACCEPT HIGH) or whether data must remain in place (ACCEPT LOW). Therefore, from Cycle 4 to Cycle 5, the data D1 is passed from Stage F to the following device, the data D2 is shifted from secondary to primary storage in Stage F, but the data D3 in Stage E is not transferred to Stage F. The data D4 and D5 can be transferred into the following pipeline stages as normal since the following stages have their ACCEPT

Comparing the state of the pipeline in Cycle 4 and Cycle 5, it can be seen that the provision of secondary storage elements, enables the pipeline embodiment shown in Fig. 2 to expand, that is, to free up data storage elements into which valid data can be advanced. For example, in Cycle 4, the data blocks D1, D2 and D3 form a "solid wall" since their data cannot be transferred until the ACCEPT signal into Stage F goes HIGH. Once this signal does become HIGH, however, data D1 is shifted out of the pipeline, data D2 is shifted into the primary storage elements of Stage F, and the secondary storage elements of Stage F become free to accept new data if the following device is not able to receive the data D2 and the pipeline must once again "compress." This is shown in Cycle 6, for which the data D3 has been shifted into the secondary storage elements of Stage F and the data D4 has been passed on from Stage D to Stage E as normal.

As shown in Fig. 3, each pipeline stage is represented as having two separate boxes which illustrate the primary and secondary storage elements. Also, although the VALID signal and the data lines connect the various pipeline stages as before, for ease of illustration, only the ACCEPT signal is shown in Fig. 3. A change of state during a clock phase of certain of the ACCEPT signals is indicated in Fig. 3 using an upward-pointing arrow for changes from LOW to HIGH. Similarly, a downward-pointing arrow for changes from HIGH to

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set HIGH since the secondary storage elements of Stage F do not contain valid data. As before, since the primary storage elements of Stage F are able to accept data, data in all the upstream primary and secondary storage elements can be shifted downstream without any valid data being overwritten. The shift of data from one stage to the next takes place during the next  $\phi 0$  phase in Cycle 2. For example, the valid data D1 contained in the primary storage element of Stage E is shifted into the secondary storage element of Stage F, the data D4 is shifted into the pipeline, that is, into the secondary storage element of Stage A, and so forth.

The primary storage element of Stage F still does not contain valid data during the  $\phi 0$  phase in Cycle 2 and, therefore, the ACCEPT signal from the primary storage elements into the secondary storage elements of Stage F remains HIGH. During the  $\phi 1$  phase in Cycle 2, data can therefore be shifted yet another step to the right, i.e., from the secondary to the primary storage elements within each stage.

However, once valid data is loaded into the primary storage elements of Stage F, if the ACCEPT into Stage F from the downstream device is still LOW, it is not possible to shift data out of the secondary storage element of Stage F without overwriting and destroying the valid data D1. The ACCEPT signal from the primary storage elements into the secondary storage elements of Stage F therefore goes LOW. Data D2, however, can still be shifted into the secondary storage of Stage F since it did not contain valid data and its ACCEPT signal out was HIGH.

During the  $\phi 1$  phase of Cycle 3, it is not possible to shift data D2 into the primary storage elements of Stage F, although data can be shifted within all the previous stages. Once valid data is loaded into the secondary storage elements of Stage F, however, Stage F is not able to pass on this

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Assume now, that the ACCEPT signal into the primary storage elements of Stage F goes LOW during the 01 phase in Cycle 5. This means that Stage F is not able to transfer the data D2 out of the pipeline. Stage F, consequently, sets the ACCEPT signal from its primary to its secondary storage elements LOW to prevent overwriting of the valid data D2. The data D2 stored in the secondary storage elements of Stage F, however, can be overwritten without loss, and the data D3, is therefore, transferred into the secondary storage elements of Stage F during the 00 phase of Cycle 6. Data D4 and D5 can be shifted downstream as normal. Once valid data D3 is stored in Stage F along with data D2, as long as the ACCEPT signal into the primary storage elements of Stage F is LOW, neither of the secondary storage elements can accept new data, and it signals this by setting the ACCEPT signal into Stage F LOW.

As this example illustrates, the concept of a "stage" in the pipeline structure illustrated in Fig. 3 is to some extent a matter of perception. Since data is transferred within a stage (from the secondary to the primary storage elements) as it is between stages (from the primary storage elements of the upstream stage into the secondary storage elements of the neighboring downstream stage), one could just as well consider a stage to consist of "primary" storage elements followed by "secondary storage elements" instead of

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As discussed previously, while other conventional timing  
5 arrangements may be used, the interface is preferably  
controlled by a two-phase, non-overlapping clock. In Figs.  
4-9, these clock phase signals are referred to as PH0 and  
PH1. In Fig. 4, a line is shown for each clock phase signal.

In the illustrated example of this embodiment, it is assumed that the Q outputs of all latches follow their D inputs, that is, they are "loaded", when the clock input is HIGH, i.e., at a logic "1" level. Additionally, the Q outputs hold their last values. In other words, the Q outputs are "latched" on the falling edge of their respective clock signals. Each latch has for its clock either one of two non-overlapping clock signals PH0 or PH1 (as shown in Fig. 5), or the logical AND combination of one of these clock signals PH0, PH1 and one logic signal. The invention works equally well, however, by providing latches that latch on the rising edges of the clock signals, or any other known latching arrangement, as long as conventional methods are applied to ensure proper timing of the latching operations.

30 The output data from the input data latch LDIN passes via an arbitrary and optional combinatorial logic circuit B1, which may be provided to convert output data from input latch LDIN into intermediate data, which is then later loaded in an output data latch LDOUT, which comprises the primary storage

elements described above. The output from the output data latch LDOUT may similarly pass through an arbitrary and optional combinatorial logic circuit B2 before being passed onward as OUT\_DATA to the next device downstream. This may  
 5 be another pipeline stage or any other device connected to the pipeline.

In the practice of the present invention, each stage of the pipeline also includes a validation input latch LVIN, a validation output latch LVOUT, an acceptance input latch  
 10 LAIN, and an acceptance output latch LAOUT. Each of these four latches is, preferably, a simple, single-stage latch. The outputs from latches LVIN, LVOUT, LAIN and LAOUT are, respectively, QVIN, QVOUT, QAIN, QAOUT. The output signal QVIN from the validation input latch is connected either  
 15 directly as an input to the validation output latch LVOUT, or via intermediate logic devices or circuits that may alter the signal.

Similarly, the output validation signal QVOUT of a given stage may be connected either directly to the input of the validation input latch QVIN of the following stage, or via  
 20 intermediate devices or logic circuits, which may alter the validation signal. This output QVIN is also connected to a logic gate (to be described below), whose output is connected to the input of the acceptance input latch LAIN. The output  
 25 QAOUT from the acceptance output latch LAOUT is connected to a similar logic gate (described below), optionally via another logic gate.

As shown in Fig. 4, the output validation signal QVOUT forms an OUT\_VALID signal that can be received by subsequent  
 30 stages as an IN\_VALID signal, or simply to indicate valid data to subsequent circuitry connected to the pipeline. The readiness of the following circuit or stage to accept data is indicated to each stage as the signal OUT\_ACCEPT, which is connected as the input to the acceptance output latch LAOUT.

preferably via logic circuitry, which is described below. Similarly, the output QAOUT of the acceptance output latch LAOUT is connected as the input to the acceptance input latch LAIN, preferably via logic circuitry, which is described  
 5 below.

In practicing the present invention, the output signals QVIN, QVOUT from the validation latches LVIN, LVOUT are combined with the acceptance signals QAOUT, OUT\_ACCEPT, respectively, to form the inputs to the acceptance latches  
 10 LAIN, LAOUT, respectively. In the embodiment illustrated in Fig. 4, these input signals are formed as the logical NAND combination of the respective validation signals QVIN, QVOUT, with the logical inverse of the respective acceptance output signals QAOUT, OUT\_ACCEPT. Conventional logic gates, NAND1  
 15 and NAND2, perform the NAND operation, and the inverters INV1, INV2 form the logical inverses of the respective acceptance signals.

As is well known in the art of digital design, the output from a NAND gate is a logical "1" when any or all of its  
 20 input signals are in the logical "0" state. The output from a NAND gate is, therefore, a logical "0" only when all of its inputs are in the logical "1" state. Also well known in the art, is that the output of a digital inverter such as INV1 is a logical "1" when its input signal is a "0" and is a "0"  
 25 when its input signal is a "1"

The inputs to the NAND gate NAND1 are, therefore, QVIN and NOT (QAOUT), where "NOT" indicates binary inversion. Using known techniques, the input to the acceptance latch LAIN can be resolved as follows:

$$20 \quad \text{NAND}(QVIN, \text{NOT}(QAOUT)) = \text{NOT}(QVIN) \text{ OR } QAOUT$$

In other words, the combination of the inverter INV1 and the NAND gate NAND1 is a logical "1" either when the signal QVIN is a "0" or the signal QAOUT is a "1", or both. The gate NAND1 and the inverter INV1 can, therefore, be

implemented by a single OR gate that has one of its inputs tied directly to the QAOUT output of the acceptance latch LAOUT and its other input tied to the inverse of the output signal QVIN of the validation input latch LVIN.

5 As is well known in the art of digital design, many latches suitable for use as the validation and acceptance latches may have two outputs, Q and NOT(Q), that is, Q and its logical inverse. If such latches are chosen, the one input to the OR gate can, therefore, be tied directly to the  
10 NOT(Q) output of the validation latch LVIN. The gate NAND1 and the inverter INV1 can be implemented using well known conventional techniques. Depending on the latch architecture used, however, it may be more efficient to use a latch without an inverting output, and to provide instead the gate  
15 NAND1 and the inverter INV1, both of which also can be implemented efficiently in a silicon device. Accordingly, any known arrangement may be used to generate the Q signal and/or its logical inverse.

The data and validation latches LDIN, LDOUT, LVIN and  
20 LVOUT, load their respective data inputs when both clock signals (PH0 at the input side and PH1 at the output side) and the output from the acceptance latch of the same side are logical "1". Thus, the clock signal (PH0 for the input latches LDIN and LVIN) and the output of the respective  
25 acceptance latch (in this case, LAIN) are used in a logical AND manner and data is loaded only when they are both logical "1".

In particular applications, such as CMOS implementations of the latches, the logical AND operation that controls the  
30 loading (via the illustrated CK or enabling "input") of the latches can be implemented easily in a conventional manner by connecting the respective enabling input signals (for example, PH0 and QAIN for the latches LVIN and LDIN), to the gates of MOS transistors connected in series in the input

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lines of the latches. Consequently, it is necessary to provide an actual logic AND gate, which might cause problems of timing due to propagation delay in high-speed applications. The AND gate shown in the figures, therefore, only indicates the logical function to be performed in generating the enable signals of the various latches.

Thus, the data latch LDIN loads input data only when PH0 and QAIN are both "1". It will latch this data when either of these two signals goes to a "0".

Although only one of the clock phase signals PH0 or PH1, is used to clock the data and validation latches at the input (and output) side of the pipeline stage, the other clock phase signal is used, directly, to clock the acceptance latch at the same side. In other words, the acceptance latch on either side (input or output) of a pipeline stage is preferably clocked "out of phase" with the data and validation latches on the same side. For example, PH1 is used to clock the acceptance input latch, although PH0 is used in generating the clock signal CK for the data latch LDIN and the validation latch LVIN.

As an example of the operation of a pipeline augmented by the two-wire validation and acceptance circuitry assume that no valid data is initially presented at the input to the circuit, either from a preceding pipeline stage, or from a transmission device. In other words, assume that the validation input signal IN\_VALID to the illustrated stage has not gone to a "1" since the system was most recently reset. Assume further that several clock cycles have taken place since the system was last reset and, accordingly, the circuitry has reached a steady-state condition. The validation input signal QVIN from the validation latch LVIN is, therefore, loaded as a "0" during the next positive period of the clock PH0. The input to the acceptance input latch LAIN (via the gate NAND1 or another equivalent gate),

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5 Note that it is not necessary to reset all of the latches that hold valid data in the pipeline. As depicted in Fig. 4, the validation input latch LVIN is not directly reset by the reset signal NOTRESET0, but rather is reset indirectly. Assume that the reset signal NOTRESET0 drops to a "0". The  
10 validation output signal QVOUT also drops to a "0", regardless of its previous state, whereupon the input to the acceptance output latch LAOUT (via the gate NAND1) goes HIGH. The acceptance output signal QAOUT also rises to a "1". This QAOUT value of "1" is then transferred as a "1" to the input  
15 of the acceptance input latch LAIN regardless of the state of the validation input signal QVIN. The acceptance input signal QAIN then rises to a "1" at the next rising edge of the clock signal PH1. Assuming that the validation signal IN\_VALID has been correctly reset to a "0", then upon the  
20 subsequent rising edge of the clock signal PH0, the output from the validation latch LVIN will become a "0", as it would have done if it had been reset directly.

As this example illustrates, it is only necessary to reset the validation latch in only one side of each stage (including the final stage) in order to reset all validation latches. In fact, in many applications, it will not be necessary to reset every other validation latch: If the reset signal NOTRESET0 can be guaranteed to be low during more than one complete cycle of both phases PH0, PH1 of the clock, then the "automatic reset" (a backwards propagation of the reset signal) will occur for validation latches in preceding pipeline stages. Indeed, if the reset signal is held low for at least as many full cycles of both phases of the clock as there are pipeline stages, it will only be

necessary to directly reset the validation output latch in the final pipeline stage.

Figs. 5a and 5b (referred to collectively as Fig. 5) illustrate a timing diagram showing the relationship between the non-overlapping clock signals PH0, PH1, the effect of the reset signal, and the holding and transfer of data for the different permutations of validation and acceptance signals into and between the two illustrated sides of a pipeline stage configured in the embodiment shown in Fig. 4. In the example illustrated in the timing diagram of Fig. 5, it has been assumed that the outputs from the data latches LDIN, LDOUT are passed without further manipulation by intervening logic blocks B1, B2. This is by way of example and not necessarily by way of limitation. It is to be understood that any combinatorial logic structures may be included between the data latches of consecutive pipeline stages, or between the input and output sides of a single pipeline stage. The actual illustrated values for the input data (for example the HEX data words "aa" or "04") are also merely illustrative. As is mentioned above, the input data bus may have any width (and may even be analog), as long as the data latches or other storage devices are able to accommodate and latch or store each bit or value of the input word.

#### Preferred Data Structure - "tokens"

In the sample application shown in Fig. 4, each stage processes all input data, since there is no control circuitry that excludes any stage from allowing input data to pass through its combinatorial logic block B1, B2, and so forth. To provide greater flexibility, the present invention includes a data structure in which "tokens" are used to distribute data and control information throughout the system. Each token consists of a series of binary bits separated into one or more blocks of token words.

Furthermore, the bits fall into one of three types: address bits (A), data bits (D), or an extension bit (E). Assume by way of example and, not necessarily by way of limitation, that data is transferred as words over an 8-bit bus with a 1-bit extension bit line. An example of a four-word token is, in order of transmission:

First word:	E	A	A	A	D	D	D	D	D
Second word:	E	D	D	D	D	D	D	D	D
Third word:	E	D	D	D	D	D	D	D	D
Fourth word:	E	D	D	D	D	D	D	D	D

Note that the extension bit E is used as an addition (preferably) to each data word. In addition, the address field can be of variable length and is preferably transmitted just after the extension bit of the first word.

Tokens, therefore, consist of one or more words of (binary) digital data in the present invention. Each of these words is transferred in sequence and preferably in parallel, although this method of transfer is not necessary: serial data transfer is also possible using known techniques. For example, in a video parser, control information is transmitted in parallel, whereas data is transmitted serially.

As the example illustrates, each token has, preferably at the start, an address field (the string of A-bits) that identifies the type of data that is contained in the token. In most applications, a single word or portion of a word is sufficient to transfer the entire address field, but this is not necessary in accordance with the invention, so long as logic circuitry is included in the corresponding pipeline stages that is able to store some representation of partial address fields long enough for the stages to receive and decode the entire address field.

Note that no dedicated wires or registers are required to transmit the address field. It is transmitted using the data bits. As is explained below, a pipeline stage will not be slowed down if it is not intended to be activated by the particular address field, i.e., the stage will be able to pass along the token without delay.

The remainder of the data in the token following the address field is not constrained by the use of tokens. These D-data bits may take on any values and the meaning attached to these bits is of no importance here. That is, the meaning of the data can vary, for example, depending upon where the data is positioned within the system at a particular point in time. The number of data bits D appended after the address field can be as long or as short as required, and the number of data words in different tokens may vary greatly. The address field and extension bit are used to convey control signals to the pipeline stages. Because the number of words in the data field (the string of D bits) can be arbitrary, as can be the information conveyed in the data field can also vary accordingly. The explanation below is, therefore, directed to the use of the address and extension bits.

In the present invention, tokens are a particularly useful data structure when a number of blocks of circuitry are connected together in a relatively simple configuration. The simplest configuration is a pipeline of processing steps. For example, in the one shown in Fig. 1. The use of tokens, however, is not restricted to use on a pipeline structure.

Assume once again that each box represents a complete pipeline stage. In the pipeline of Fig. 1, data flows from left to right in the diagram. Data enters the machine and passes into processing Stage A. This may or may not modify the data and it then passes the data to Stage B. The modification, if any, may be arbitrarily complicated and, in general, there will not be the same number of data items

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It is not necessary, in accordance with the present invention, to use the state of the extension bit to signal the last word of a given token by giving it an extension bit

set to "0". One alternative to the preferred scheme is to move the extension bit so that it indicates the first word of a token instead of the last. This can be accomplished with appropriate changes in the decoding hardware.

5       The advantage of using the extension bit of the present invention to signal the last word in a token rather than the first, is that it is often useful to modify the behavior of a block of circuitry depending upon whether or not a token has extension bits. An example of this is a token that  
10       activates a stage that processes video quantization values stored in a quantization table (typically a memory device). For example, a table containing 64 eight-bit arbitrary binary integers.

      In order to load a new quantization table into the  
15       quantizer stage of the pipeline, a "QUANT\_TABLE" token is sent to the quantizer. In such a case the token, for example, consists of 65 token words. The first word contains the code "QUANT\_TABLE", i.e., build a quantization table. This is followed by 64 words, which are the integers of the  
20       quantization table.

      When encoding video data, it is occasionally necessary to transmit such a quantization table. In order to accomplish this function, a QUANT\_TABLE token with no extension words can be sent to the quantizer stage. On seeing this token,  
25       and noting that the extension bit of its first word is LOW, the quantizer stage can read out its quantization table and construct a QUANT\_TABLE token which includes the 64 quantization table values. The extension bit of the first word (which was LOW) is changed so that it is HIGH and the  
30       token continues, with HIGH extension bits, until the new end of the token, indicated by a LOW extension bit on the sixty fourth quantization table value. This proceeds in the typical way through the system and is encoded into the bit stream.

5       The choice of whether to use the extension bit to signal the first or last token word in a token will, therefore, depend on the system in which the pipeline will be used. Both alternatives are possible in accordance with the invention.

Although there are, therefore, uses for long tokens,  
20 experience has shown that there are many uses for short  
tokens. Here the preferred extension bit scheme is  
advantageous. If a token is only one word long, then only  
one bit is required to signal this. However, a counting  
scheme would typically require the same ten bits as before.

25        Disadvantages of a length count scheme include the following: 1) it is inefficient for short tokens; 2) it places a maximum length restriction on a token (with only ten bits, no more than 1023 words can be counted); 3) the length of a token must be known in advance of generating the count  
30        (which is presumably at the start of the token); 4) every block of circuitry that deals with tokens would need to be provided with hardware to count words; and 5) if the count should get corrupted (due to a data transmission error) it is not clear whether recovery can be achieved.





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will be able to deal with the new token without modification to their designs because they will not recognize it and will, accordingly, pass that token on unmodified.

5 This ability of the present invention to leave substantially existing designed devices unaffected has clear advantages. It may be possible to leave some semiconductor chips in a chip set completely unaffected by a design improvement in some other chips in the set. This is advantageous both from the perspective of a customer and from  
10 that of a chip manufacturer. Even if modifications mean that all chips are affected by the design change (a situation that becomes increasingly likely as levels of integration progress so that the number of chips in a system drops) there will still be the considerable advantage of better time-to-market  
15 than can be achieved, since the same design can be reused.

In particular, note the situation that occurs when it becomes necessary to extend the token set to include two word addresses. Even in this case, it is still not necessary to modify an existing design. Token decoders in the pipeline  
20 stages will attempt to decode the first word of such a token and will conclude that it does not recognize the token. It will then pass on the token unmodified using the extension bit to perform this operation correctly. It will not attempt to decode the second word of the token (even though this  
25 contains address bits) because it will "assume" that the second word is part of the data field of a token that it does not recognize.

In many cases, a pipeline stage or a connected block of circuitry will modify a token. This usually, but not  
30 necessarily, takes the form of modifying the data field of a token. In addition, it is common for the number of data words in the token to be modified, either by removing certain data words or by adding new ones. In some cases, tokens are removed entirely from the token stream.

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In most applications, pipeline stages will typically only decode (be activated by) a few tokens; the stage does not recognize other tokens and passes them on unaltered. In a large number of cases, only one token is decoded, the DATA  
5 Token word itself.

In many applications, the operation of a particular stage will depend upon the results of its own past operations. The "state" of the stage, thus, depends on its previous states. In other words, the stage depends upon stored state  
10 information, which is another way of saying it must retain some information about its own history one or more clock cycles ago. The present invention is well-suited for use in pipelines that include such "state machine" stages, as well as for use in applications in which the latches in the data  
15 path are simple pipeline latches.

The suitability of the two-wire interface, in accordance with the present invention, for such "state machine" circuits is a significant advantage of the invention. This is especially true where a data path is being controlled by a  
20 state machine. In this case, the two-wire interface technique above-described may be used to ensure that the "current state" of the machine stays in step with the data which it is controlling in the pipeline.

Fig. 6 shows a simplified block diagram of one example of  
25 circuitry included in a pipeline stage for decoding a token address field. This illustrates a pipeline stage that has the characteristics of a "state machine". Each word of a token includes an "extension bit" which is HIGH if there are more words in the token or LOW if this is the last word of  
30 the token. If this is the last word of a token, the next valid data word is the start of a new token and, therefore, its address must be decoded. The decision as to whether or not to decode the token address in any given word, thus, depends upon knowing the value of the previous extension bit.

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For the sake of simplicity only, the two-wire interface (with the acceptance and validation signals and latches) is not illustrated and all details dealing with resetting the circuit are omitted. As before, an 8-bit data word is  
 5 assumed by way of example only and not by way of limitation.

This exemplifying pipeline stage delays the data bits and the extension bit by one pipeline stage. It also decodes the DATA Token. At the point when the first word of the DATA Token is presented at the output of the circuit, the signal  
 10 "DATA\_ADDR" is created and set HIGH. The data bits are delayed by the latches LDIN and LDOUT, each of which is repeated eight times for the eight data bits used in this example (corresponding to an 8-input, 8-output latch). Similarly, the extension bit is delayed by extension bit  
 15 latches LEIN and LEOUT.

In this example, the latch LEPREV is provided to store the most recent state of the extension bit. The value of the extension bit is loaded into LEIN and is then loaded into LEOUT on the next rising edge of the non-overlapping clock  
 20 phase signal PH1. Latch LEOUT, thus, contains the value of the current extension bit, but only during the second half of the non-overlapping, two-phase clock. Latch LEPREV, however, loads this extension bit value on the next rising edge of the clock signal PH0, that is, the same signal that enables the  
 25 extension bit input latch LEIN. The output QEPREV of the latch LEPREV, thus, will hold the value of the extension bit during the previous PH0 clock phase.

The five bits of the data word output from the inverting Q output, plus the non-inverted MD[2], of the latch LDIN are  
 30 combined with the previous extension bit value QEPREV in a series of logic gates NAND1, NAND2, and NOR1, whose operations are well known in the art of digital design. The designation "N\_MD[m] indicates the logical inverse of bit m of the mid-data word MD[7:0]. Using known techniques of

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Boolean algebra, it can be shown that the output signal SA from this logic block (the output from NOR1) is HIGH (a "1") only when the previous extension bit is a "0" (QPREV="0") and the data word at the output of the non-inverting Q latch (the original input word) LDIN has the structure "000001xx", that is, the five high-order bits MD[7]-MD[3] bits are all "0" and the bit MD[2] is a "1" and the bits in the Zero-one positions have any arbitrary value.

There are, thus, four possible data words (there are four permutations of "xx") that will cause SA and, therefore, the output of the address signal latch LADDR to whose input SA is connected, to become HIGH. In other words, this stage provides an activation signal (DATA\_ADDR = "1") only when one of the four possible proper tokens is presented and only when the previous extension bit was a zero, that is, the previous data word was the last word in the previous series of token words, which means that the current token word is the first one in the current token.

When the signal QPREV from latch LEPREV is LOW, the value at the output of the latch LDIN is therefore the first word of a new token. The gates NAND1, NAND2 and NOR1 decode the DATA token (000001xx). This address decoding signal SA is, however, delayed in latch LADDR so that the signal DATA\_ADDR has the same timing as the output data OUT\_DATA and OUT\_EXTN.

Fig. 7 is another simple example of a state-dependent pipeline stage in accordance with the present invention, which generates the signal LAST\_OUT\_EXTN to indicate the value of the previous output extension bit OUT\_EXTN. One of the two enabling signals (at the CK inputs) to the present and last extension bit latches, LEOUT and LEPREV, respectively, is derived from the gate AND1 such that these latches only load a new value for them when the data is valid and is being accepted (the Q outputs are HIGH from the output validation and acceptance latches LVOUT and LAOUT,

000001xx

respectively). In this way, they only hold valid extension bits and are not loaded with spurious values associated with data that is not valid. In the embodiment shown in Fig. 7, the two-wire valid/accept logic includes the OR1 and OR2 gates with input signals consisting of the downstream acceptance signals and the inverting output of the validation latches LVIN and LVOUT, respectively. This illustrates one way in which the gates NAND1/2 and INV1/2 in Fig. 4 can be replaced if the latches have inverting outputs.

Although this is an extremely simple example of a "state-dependent" pipeline stage, i.e., since it depends on the state of only a single bit, it is generally true that all latches holding state information will be updated only when data is actually transferred between pipeline stages. In other words, only when the data is both valid and being accepted by the next stage. Accordingly, care must be taken to ensure that such latches are properly reset.

The generation and use of tokens in accordance with the present invention, thus, provides several advantages over known encoding techniques for data transfer through a pipeline.

First, the tokens, as described above, allow for variable length address fields (and can utilize Huffman coding for example) to provide efficient representation of common tokens.

Second, consistent encoding of the length of a token allows the end of a token (and hence the start of the next token) to be processed correctly (including simple non-manipulative transfer), even if the token is not recognized by the token decoder circuitry in a given pipeline stage.

Third, rules and hardware structures for the handling of unrecognized tokens (that is, for passing them on unmodified, allow communication between one stage and a downstream stage that is not its nearest neighbor in the pipeline. This also

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increases the expandability and efficient adaptability of the pipeline since it allows for future changes in the token set without requiring large scale redesigning of existing pipeline stages. The tokens of the present invention are particularly useful when used in conjunction with the two-wire interface that is described above and below.

As an example of the above, Figs. 8a and 8b, taken together (and referred to collectively below as Fig. 8), depict a block diagram of a pipeline stage whose function is as follows. If the stage is processing a predetermined token (known in this example as the DATA token), then it will duplicate every word in this token with the exception of the first one, which includes the address field of the DATA token. If, on the other hand, the stage is processing any other kind of token, it will delete every word. The overall effect is that, at the output, only DATA Tokens appear and each word within these tokens is repeated twice.

Many of the components of this illustrated system may be the same as those described in the much simpler structures shown in Figs. 4, 6, and 7. This illustrates a significant advantage. More complicated pipeline stages will still enjoy the same benefits of flexibility and elasticity, since the same two-wire interface may be used with little or no adaptation.

The data duplication stage shown in Fig. 8 is merely one example of the endless number of different types of operations that a pipeline stage could perform in any given application. This "duplication stage" illustrates, however, a stage that can form a "bottleneck", so that the pipeline according to this embodiment will "pack together".

A "bottleneck" can be any stage that either takes a relatively long time to perform its operations, or that creates more data in the pipeline than it receives. This example also illustrates that the two-wire accept/valid

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internal control signals used to duplicate data. These include a "DATA\_TOKEN" signal that indicates that the circuitry is currently processing a valid DATA Token, and a NOT\_DUPLICATE signal which is used to control duplication of data. When the circuitry is processing a DATA Token, the NOT\_DUPLICATE signal toggles between a HIGH and a LOW state and this causes each word in the token to be duplicated once (but no more times). When the circuitry is not processing a valid DATA Token then the NOT\_DUPLICATE signal is held in a HIGH state. Accordingly, this means that the token words that are being processed are not duplicated.

As Fig. 8a illustrates, the upper six bits of 8-bit intermediate data word and the output signal QI1 from the latch LI1 form inputs to a group of logic gates NOR1, NOR2, NAND18. The output signal from the gate NAND18 is labeled S1. Using well-known Boolean algebra, it can be shown that the signal S1 is a "0" only when the output signal QI1 is a "1" and the MID\_DATA word has the following structure: "000001xx", that is, the upper five bits are all "0", the bit MID\_DATA[2] is a "1" and the bits in the MID\_DATA[1] and MID\_DATA[0] positions have any arbitrary value. Signal S1, therefore, acts as a "token identification signal" which is low only when the MID\_DATA signal has a predetermined structure and the output from the latch LI1 is a "1". The nature of the latch LI1 and its output QI1 is explained further below.

Latch LO1 performs the function of latching the last value of the intermediate extension bit (labeled "MID\_EXTN" and as signal S4), and it loads this value on the next rising edge of the clock phase PHO into the latch LI1, whose output is the bit QI1 and is one of the inputs to the token decoding logic group that forms signal S1. Signal S1, as is explained above, may only drop to a "0" if the signal QI1 is a "1" (and the MID\_DATA signal has the predetermined structure). Signal

000001xx

5       The latches LO2 and LI2 together with the NAND gates  
NAND20 and NAND22 form storage for the signal, DATA\_TOKEN.  
In the normal situation, the signal QI1 at the input to  
NAND20 and the signal S1 at the input to NAND22 will both be  
at logic "1". It can be shown, again by the techniques of  
10      Boolean algebra, that in this situation these NAND gates  
operate in the same manner as inverters, that is, the signal  
QI2 from the output of latch LI2 is inverted in NAND20 and  
then this signal is inverted again by NAND22 to form the  
signal S2. In this case, since there are two logical  
15      inversions in this path, the signal S2 will have the same  
value as QI2.

It can also be seen that the signal DATA\_TOKEN at the output of latch LO2 forms the input to latch LI2. As a result, as long as the situation remains in which both QI1 and S1 are HIGH, the signal DATA\_TOKEN will retain its state (whether "0" or "1"). This is true even though the clock signals PH0 and PH1 are clocking the latches (LI2 and LO2 respectively). The value of DATA\_TOKEN can only change when one or both of the signals QI1 and S1 are "0".

25 As explained earlier, the signal QI1 will be "0" when the previous extension bit was "0". Thus, it will be "0" whenever the MID\_DATA value is the first word of a token (and, thus, includes the address field for the token). In this situation, the signal S1 may be either "0" or "1". As  
30 explained earlier, signal S1 will be "0" if the MID\_DATA word has the predetermined structure that in this example indicates a "DATA" Token. If the MID\_DATA word has any other structure, (indicating that the token is some other token, not a DATA Token), S1 will be "1".

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In addition, as Fig. 8 shows, the OUT\_VALID signal will be forced low during the entire token unless the first data word

has the structure described above. This has the effect that all tokens except the one that causes the duplication process will be deleted from the token stream, since a device connected to the output terminals (OUTDATA, OUTEXTN and OUTVALID) will not recognize these token words as valid data.

As before, both validation latches LVIN, LVOUT in the stage can be reset by a single conductor NOT\_RESETO, and a single resetting input R on the downstream latch LVOUT, with the reset signal being propagated backwards to cause the upstream validation latch to be forced low on the next clock cycle.

It should be noted that in the example shown in Fig. 8, the duplication of data contained in DATA tokens serves only as an example of the way in which circuitry may manipulate the ACCEPT and VALID signals so that more data is leaving the pipeline stage than that which is arriving at the input. Similarly, the example in Fig. 8 removes all non-DATA tokens purely as an illustration of the way in which circuitry may manipulate the VALID signal to remove data from the stream. In most typical applications, however, a pipeline stage will simply pass on any tokens that it does not recognize, unmodified, so that other stages further down the pipeline may act upon them if required.

Figs. 9a and 9b taken together illustrate an example of a timing diagram for the data duplication circuit shown in Figs. 8a and 8b. As before, the timing diagram shows the relationship between the two-phase clock signals, the various internal and external control signals, and the manner in which data is clocked between the input and output sides of the stage and is duplicated.

Referring now more particularly to Figure 10, there is shown a reconfigurable process stage in accordance with one

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aspect of the present invention.

Input latches 34 receive an input over a first bus 31. A first output from the input latches 34 is passed over line 32 to a token decode subsystem 33. A second output from the input latches 34 is passed as a first input over line 35 to a processing unit 36. A first output from the token decode subsystem 33 is passed over line 37 as a second input to the processing unit 36. A second output from the token decode 33 is passed over line 40 to an action identification unit 39. The action identification unit 39 also receives input from registers 43 and 44 over line 46. The registers 43 and 44 hold the state of the machine as a whole. This state is determined by the history of tokens previously received. The output from the action identification unit 39 is passed over line 38 as a third input to the processing unit 36. The output from the processing unit 36 is passed to output latches 41. The output from the output latches 41 is passed over a second bus 42.

Referring now to Figure 11, a Start Code Detector (SCD) 51 receives input over a two-wire interface 52. This input can be either in the form of DATA tokens or as data bits in a data stream. A first output from the Start Code Detector 51 is passed over line 53 to a first logical first-in first-out buffer (FIFO) 54. The output from the first FIFO 54 is logically passed over line 55 as a first input to a Huffman decoder 56. A second output from the Start Code Detector 51 is passed over line 57 as a first input to a DRAM interface 58. The DRAM interface 58 also receives input from a buffer manager 59 over line 60. Signals are transmitted to and received from external DRAM (not shown) by the DRAM interface 58 over line 61. A first output from the DRAM interface 58 is passed over line 62 as a first physical input to the Huffman decoder 56.

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The output from the Huffman decoder 56 is passed over line 63 as an input to an Index to Data Unit (ITOD) 64. The Huffman decoder 56 and the ITOD 64 work together as a single logical unit. The output from the ITOD 64 is passed over line 65 to an arithmetic logic unit (ALU) 66. A first output from the ALU 66 is passed over line 67 to a read-only memory (ROM) state machine 68. The output from the ROM state machine 68 is passed over line 69 as a second physical input to the Huffman decoder 56. A second output from the ALU 66 is passed over line 70 to a Token Formatter (T/F) 71.

A first output 72 from the T/F 71 of the present invention is passed over line 72 to a second FIFO 73. The output from the second FIFO 73 is passed over line 74 as a first input to an inverse modeller 75. A second output from the T/F 71 is passed over line 76 as a third input to the DRAM interface 58. A third output from the DRAM interface 58 is passed over line 77 as a second input to the inverse modeller 75. The output from the inverse modeller 75 is passed over line 78 as an input to an inverse quantizer 79. The output from the inverse quantizer 79 is passed over line 80 as an input to an inverse zig-zag (IZZ) 81. The output from the IZZ 81 is passed over line 82 as an input to an inverse discrete cosine transform (IDCT) 83. The output from the IDCT 83 is passed over line 84 to a temporal decoder (not shown).

Referring now more particularly to Figure 12, a temporal decoder in accordance with the present invention is shown. A fork 91 receives as input over line 92 the output from the IDCT 83 (shown in Fig. 11). As a first output from the fork 91, the control tokens, e.g., motion vectors and the like, are passed over line 93 to an address generator 94. Data tokens are also passed to the address generator 94 for counting purposes. As a second output from the fork 91, the

data is passed over line 95 to a FIFO 96. The output from the FIFO 96 is then passed over line 97 as a first input to a summer 98. The output from the address generator 94 is passed over line 99 as a first input to a DRAM interface 100. Signals are transmitted to and received from external DRAM (not shown) by the DRAM interface 100 over line 101. A first output from the DRAM interface 100 is passed over line 102 to a prediction filter 103. The output from the prediction filter 103 is passed over line 104 as a second input to the summer 98. A first output from the summer 98 is passed over line 105 to output selector 106. A second output from the summer 98 is passed over line 107 as a second input to the DRAM interface 100. A second output from the DRAM interface 100 is passed over line 108 as a second input to the output selector 106. The output from the output selector 106 is passed over line 109 to a Video Formatter (not shown in Figure 12).

Referring now to Figure 13, a fork 111 receives input from the output selector 106 (shown in Figure 12) over line 112. As a first output from the fork 111, the control tokens are passed over line 113 to an address generator 114. The output from the address generator 114 is passed over line 115 as a first input to a DRAM interface 116. As a second output from the fork 111 the data is passed over line 117 as a second input to the DRAM interface 116. Signals are transmitted to and received from external DRAM (not shown) by the DRAM interface 116 over line 118. The output from the DRAM interface 116 is passed over line 119 to a display pipe 120.

It will be apparent from the above descriptions that each line may comprise a plurality of lines, as necessary.

Referring now to Figure 14a, in the MPEG standard a picture 131 is encoded as one or more slices 132. Each slice 132 is, in turn, comprised of a plurality of blocks 133, and is encoded row-by-row, left-to-right in each row. As is shown, each slice 132 may span exactly one full line of blocks 133, less than one line B or D of blocks 133 or multiple lines C of blocks 133.

Referring to Figure 14b, in the JPEG and H.261 standards, the Common Intermediate Format (CIF) is used, wherein a picture 141 is encoded as 6 rows each containing 2 groups of blocks (GOBs) 142. Each GOB 142 is, in turn, composed of either 3 rows or 6 rows of an indeterminate number of blocks 143. Each GOB 142 is encoded in a zigzag direction indicated by the arrow 144. The GOBs 142 are, in turn, processed row-by-row, left-to-right in each row.

Referring now to Figure 14c, it can be seen that, for both MPEG and CIF, the output of the encoder is in the form of a data stream 151. The decoder receives this data stream 151. The decoder can then reconstruct the image according to the format used to encode it. In order to allow the decoder to recognize start and end points for each standard, the data stream 151 is segmented into lengths of 33 blocks 152.

Referring to Figure 15, a Venn diagram is shown, representing the range of values possible for the table selection from the Huffman decoder 56 (shown in Fig. 11) of the present invention. The values possible for an MPEG decoder and an H.261 decoder overlap, indicating that a single table selection will decode both certain MPEG and certain H.261 formats. Likewise, the values possible for an MPEG decoder and a JPEG decoder overlap, indicating that a single table selection will decode both certain MPEG and

certain JPEG formats. Additionally, it is shown that the H.261 values and the JPEG values do not overlap, indicating that no single table selection exists that will decode both formats.

5                   Referring now more particularly to Figure 16, there is shown a schematic representation of variable length picture data in accordance with the practice of the present invention. A first picture 161 to be processed contains a first PICTURE\_START token 162, first picture information of  
10   indeterminate length 163, and a first PICTURE\_END token 164. A second picture 165 to be processed contains a second PICTURE\_START token 166, second picture information of indeterminate length 167, and a second PICTURE\_END token 168. The PICTURE\_START tokens 162 and 166 indicate the start of  
15   the pictures 161 and 165 to the processor. Likewise, the PICTURE\_END tokens 164 and 168 signify the end of the pictures 161 and 165 to the processor. This allows the processor to process picture information 163 and 167 of variable lengths.

20                   Referring to Figure 17, a split 171 receives input over line 172. A first output from the split 171 is passed over line 173 to an address generator 174. The address generated by the address generator 174 is passed over line 175 to a DRAM interface 176. Signals are transmitted to and  
25   received from external DRAM (not shown) by the DRAM interface 176 over line 177. A first output from the DRAM interface 176 is passed over line 178 to a prediction filter 179. The output from the prediction filter 179 is passed over line 180 as a first input to a summer 181. A second output from the  
30   split 171 is passed over line 182 as an input to a first-in first-out buffer (FIFO) 183. The output from the FIFO 183 is passed over line 184 as a second input to the summer 181. The output from the summer 181 is passed over line 185 to a

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value register 221 receives image data over a line 222. The line 222 is eight bits wide, allowing for parallel transmission of eight bits at a time. The output from the value register 221 is passed serially over line 223 to a  
5 decode register 224. A first output from the decode register 224 is passed to a detector 225 over a line 226. The line 226 is twenty-four bits wide, allowing for parallel transmission of twenty-four bits at a time. The detector 225 detects the presence or absence of an image which corresponds  
10 to a standard-independent start code of 23 "zero" values followed by a single "one" value. An 8-bit data value image follows a valid start code image. On detecting the presence of a start code image, the detector 225 transmits a start image over a line 227 to a value decoder 228.

15 A second output from the decode register 224 is passed serially over line 229 to a value decode shift register 230. The value decode shift register 230 can hold a data value image fifteen bits long. The 8-bit data value following the start code image is shifted to the right of the  
20 value decode shift register 230, as indicated by area 231. This process eliminates overlapping start code images, as discussed below. A first output from the value decode shift register 230 is passed to the value decoder 228 over a line 232. The line 232 is fifteen bits wide, allowing for  
25 parallel transmission of fifteen bits at a time. The value decoder 228 decodes the value image using a first look-up table (not shown). A second output from the value decode shift register 230 is passed to the value decoder 228 which passes a flag to an index-to-tokens converter 234 over a line  
30 235. The value decoder 228 also passes information to the index-to-tokens converter 234 over a line 236. The information is either the data value image or start code index image obtained from the first look-up table. The flag

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indicates which form of information is passed. The line 236 is fifteen bits wide, allowing for parallel transmission of fifteen bits at a time. While 15 bits has been chosen here as the width in the present invention it will be appreciated that bits of other lengths may also be used. The index-to-tokens converter 234 converts the information to token images using a second look-up table (not shown) similar to that given in Table 12-3 of the Users Manual. The token images generated by the index-to-tokens converter 234 are then output over a line 237. The line 237 is fifteen bits wide, allowing for parallel transmission of fifteen bits at a time.

Referring to Figure 21, a data stream 241 consisting of individual bits 242 is input to a Start Code Detector (not shown in Figure 21). A first start code image 243 is detected by the Start Code Detector. The Start Code Detector then receives a first data value image 244. Before processing the first data value image 244, the Start Code Detector may detect a second start code image 245, which overlaps the first data value image 244 at a length 246. If this occurs, the Start Code Detector does not process the first data value image 244, and instead receives and processes a second data value image 247.

Referring now to Figure 22, a flag generator 251 receives data as a first input over a line 252. The line 252 is fifteen bits wide, allowing for parallel transmission of fifteen bits at a time. The flag generator 251 also receives a flag as a second input over a line 253, and receives an input valid image over a first two-wire interface 254. A first output from the flag generator 251 is passed over a line 255 to an input valid register (not shown). A second output from the flag generator 251 is passed over a line 256 to a decode index 257. The decode index 257 generates four outputs; a picture start image is passed over a line 258, a

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picture number image is passed over a line 259, an insert image is passed over a line 260, and a replace image is passed over a line 261. The data from the flag generator 251 is passed over a line 262a. A header generator 263 uses a look-up table to generate a replace image, which is passed over a line 262b. An extra word generator 264 uses the MPU to generate an insert image, which is passed over a line 262c. Line 262a, and line 262b combine to form a line 262, which is first input to output latches 265. The output latches 265 pass data over a line 266. The line 266 is fifteen bits wide, allowing for parallel transmission of fifteen bits at a time.

The input valid register (not shown) passes an image as a first input to a first OR gate 267 over a line 268. An insert image is passed over a line 269 as a second input to the first OR gate 267. The output from the first OR gate 267 is passed as a first input to a first AND gate 270 over a line 271. The logical negation of a remove image is passed over a line 272 as a second input to the first AND gate 270 is passed as a second input to the output latches 265 over a line 273. The output latches 265 pass an output valid image over a second two-wire interface 274. An output accept image is received over the second two-wire interface 274 by an output accept latch 275. The output from the output accept latch 275 is passed to an output accept register (not shown) over a line 276.

The output accept register (not shown) passes an image as a first input to a second OR gate 277 over a line 278. The logical negation of the output from the input valid register is passed as a second input to the second OR gate 277 over a line 279. The remove image is passed over a line 280 as a third input to the second OR gate 277. The output from the second OR gate 277 is passed as a first input to a second AND gate 281 over a line 282. The logical negation of

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an insert image is passed as a second input to the second AND gate 281 over a line 283. The output from the second AND gate 281 is passed over a line 284 to an input accept latch 285. The output from the input accept latch 285 is passed  
5 over the first two-wire interface 254.

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TABLE 600

	<u>Format</u>	<u>Image Received</u>	<u>Tokens Generated</u>
1.	H.261	SEQUENCE START	SEQUENCE START
	MPEG	PICTURE START	GROUP START
5	JPEG	(None)	PICTURE START
			PICTURE DATA
2.	H.261	(None)	PICTURE END
	MPEG	(None)	PADDING
	JPEG	(None)	FLUSH
10			STOP AFTER PICTURE

As set forth in Table 600 which shows a relationship between the absence or presence of standard signals in the certain machine independent control tokens, the detection of an image by the Start Code Detector 51 generates a sequence of machine independent Control Tokens. Each image listed in the "Image Received" column starts the generation of all machine independent control tokens listed in the group in the "Tokens Generated" column. Therefore, as shown in line 1 of Table 600, whenever a "sequence start" image is received during H.261 processing or a "picture start" image is received during MPEG processing, the entire group of four control tokens is generated, each followed by its corresponding data value or values. In addition, as set forth at line 2 of Table 600, the second group of four control tokens is generated at the proper time irrespective of images received by the Start Code Detector 51.

TABLE 601

DISPLAY ORDER: I1 B2 B3 P4 B5 B6 P7 B8 B9 I10  
 TRANSMIT ORDER: I1 P4 B2 B3 P7 B5 B6 I10 B8 B9

As shown in line 1 of Table 601 which shows the timing relationship between transmitted pictures and displayed pictures, the picture frames are displayed in numerical order. However, in order to reduce the number of frames that

must be stored in memory, the frames are transmitted in a different order. It is useful to begin the analysis from an intraframe (I frame). The I1 frame is transmitted in the order it is to be displayed. The next predicted frame (P frame), P4, is then transmitted. Then, any bi-directionally interpolated frames (B frames) to be displayed between the I1 frame and P4 frame are transmitted, represented by frames B2 and B3. This allows the transmitted B frames to reference a previous frame (forward prediction) or a future frame (backward prediction). After transmitting all the B frames to be displayed between the I1 frame and the P4 frame, the next P frame, P7, is transmitted. Next, all the B frames to be displayed between the P4 and P7 frames are transmitted, corresponding to B5 and B6. Then, the next I frame, I10, is transmitted. Finally, all the B frames to be displayed between the P7 and I10 frames are transmitted, corresponding to frames B8 and B9. This ordering of transmitted frames requires only two frames to be kept in memory at any one time, and does not require the decoder to wait for the transmission of the next P frame or I frame to display an interjacent B frame.

Further information regarding the structure and operation, as well as the features, objects and advantages, of the invention will become more readily apparent to one of ordinary skill in the art from the ensuing additional detailed description of illustrative embodiment of the invention which, for purposes of clarity and convenience of explanation are grouped and set forth in the following sections:

1. Multi-Standard Configurations
2. JPEG Still Picture Decoding
3. Motion Picture Decompression
4. RAM Memory Map
5. Bitstream Characteristics

6. Reconfigurable Processing Stage
7. Multi-Standard Coding
8. Multi-Standard Processing Circuit-2nd Mode of Operation
9. Start Code Detector
- 5 10. Tokens
11. DRAM Interface
12. Prediction Filter
13. Accessing Registers
14. Microprocessor Interface (MPI)
- 10 15. MPI Read Timing
16. MPI Write Timing
17. Key Hole Address Locations
18. Picture End
19. Flushing Operation
- 15 20. Flush Function
21. Stop-After-Picture
22. Multi-Standard Search Mode
23. Inverse Modeler
24. Inverse Quantizer
- 20 25. Huffman Decoder and Parser
26. Diverse Discrete Cosine Transformer
27. Buffer Manager

## 1. MULTI-STANDARD CONFIGURATIONS

Since the various compression standards, i.e., JPEG, MPEG and H.261, are well known, as for example as described in the aforementioned United States Patent No. 5,212,742, the detailed specifications of those standards are not repeated here.

As previously mentioned, the present invention is capable of decompressing a variety of differently encoded, picture data bitstreams. In each of the different standards of encoding, some form of output formatter is required to take the data presented at the output of the spatial decoder operating alone, or the serial output of a spatial decoder and temporal decoder operating in combination, (as subsequently described herein in greater detail) and reformatting this output for use, including display in a computer or other display systems, including a video display system. Implementation of this formatting varies significantly between encoding standards and/or the type of display selected.

In a first embodiment, in accordance with the present invention, as previously described with reference to Figures 10-12 an address generator is employed to store a block of formatted data, output from either the first decoder (Spatial Decoder) or the combination of the first decoder (Spatial Decoder) and the second decoder (the Temporal Decoder), and to write the decoded information into and/or from a memory in a raster order. The video formatter described hereinafter provides a wide range of output signal combinations.

In the preferred multi-standard video decoder embodiment of the present invention, the Spatial Decoder and the Temporal Decoder are required to implement both an MPEG encoded signal and an H.261 video decoding system. The DRAM interfaces on both devices are configurable to allow the quantity of DRAM required to be reduced when working with

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small picture formats and at low coded data rates. The reconfiguration of these DRAMs will be further described hereinafter with reference to the DRAM interface. Typically, a single 4 megabyte DRAM is required by each of the Temporal Decoder and the Spatial Decoder circuits.

The Spatial Decoder of the present invention performs all the required processing within a single picture. This reduces the redundancy within one picture.

The Temporal Decoder reduces the redundancy between the subject picture with relationship to a picture which arrives prior to the arrival of the subject picture, as well as a picture which arrives after the arrival of the subject picture. One aspect of the Temporal Decoder is to provide an address decode network which handles the complex addressing needs to read out the data associated with all of these pictures with the least number of circuits and with high speed and improved accuracy.

As previously described with reference to Figure 11, the data arrives through the Start Code Detector, a FIFO register which precedes a Huffman decoder and parser, through a second FIFO register, an inverse modeller, an inverse quantizer, inverse zigzag and inverse DCT. The two FIFOs need not be on the chip. In one embodiment, the data does not flow through a FIFO that is on the chip. The data is applied to the DRAM interface, and the FIFO-IN storage register and the FIFO-OUT register is off the chip in both cases. These registers, whose operation is entirely independent of the standards, will subsequently be described herein in further detail.

The majority of the subsystems and stages shown in Figure 11 are actually independent of the particular standard used and include the DRAM interface 58, the buffer manager 59 which is generating addresses for the DRAM interface, the inverse modeller 75, the inverse zig-zag 81 and the inverse

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DCT 83. The standard independent units within the Huffman decoder and parser include the ALU 66 and the token formatter 71.

Referring now to Figure 12, the standard-independent units include the DRAM interface 100, the fork 91, the FIFO register 96, the summer 98 and the output selector 106. The standard dependent units are the address generator 94, which is different in H.261 and in MPEG, and the prediction filter 103, which is reconfigurable to have the ability to do both H.261 and MPEG. The JPEG data will flow through the entire machine completely unaltered.

Figure 13 depicts a high level block diagram of the video formatter chip. The vast majority of this chip is independent of the standard. The only items that are affected by the standard is the way the data is written into the DRAM in the case of H.261, which differs from MPEG or JPEG; and that in H.261, it is not necessary to code every single picture. There is some timing information referred to as a temporal reference which provides some information regarding when the pictures are intended to be displayed, and that is also handled by the address generation type of logic in the video formatter.

The remainder of the circuitry embodied in the video formatter, including all of the color space conversion, the up-sampling filters and all of the gamma correction RAMs, is entirely independent of the particular compression standard utilized.

The Start Code Detector of the present invention is dependent on the compression standard in that it has to recognize different start code patterns in the bitstream for each of the standards. For example, H.261 has a 16 bit start code, MPEG has a 24 bit start code and JPEG uses marker codes which are fairly different from the other start codes. Once the Start Code Detector has recognized those different start

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and issues the correct command to the Huffman decoder at different times consistent with the standard in operation.

5 The last unit on the chip that is dependent on the compression standard is the inverse quantizer 79, where the mathematics that the inverse quantizer performs are different for each of the different standards. In this regard, a CODING\_STANDARD token is decoded and the inverse quantizer 79 remembers which standard it is operating in. Then, any subsequent DATA tokens that happen after that event, but  
10 before another CODING\_STANDARD may come along, are dealt with in the way indicated by the CODING\_STANDARD that has been remembered inside the inverse quantizer. In the detailed description, there is a table illustrating different parameters in the different standards and what circuitry is  
15 responding to those different parameters or mathematics.

The address generation, with reference to H.261, differs for each of the subsystems shown in Figure 12 and Figure 13. The address generation in Figure 11, which generates addresses for the two FIFOs before and after the Huffman  
20 decoder, does not change depending on the coding standards. Even in H.261, the address generation that happens on that chip is unaltered. Essentially, the difference between these standards is that in MPEG and JPEG, there is an organization of macroblocks that are in linear lines going horizontally  
25 across pictures. As best observed in Figure 14a, a first macroblock A covers one full line. A macroblock B covers less than a line. A macroblock C covers multiple lines. The division in MPEG is into slices 132, and a slice may be one horizontal line, A, or it may be part of a horizontal line B, or it may extend from one line into the next line, C. Each  
30 of these slices 132 is made up of a row of macroblocks.

In H.261, the organization is rather different because the picture is divided into groups of blocks (GOB).

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A group of blocks is three rows of macroblocks high by eleven macroblocks wide. In the case of a CIF picture, there are twelve such groups of blocks. However, they are not organized one above the other. Rather, there are two groups  
5 of blocks next to each other and then six high, i.e., there are 6 GOB's vertically, and 2 GOB's horizontally.

In all other standards, when performing the addressing, the macroblocks are addressed in order as described above. More specifically, addressing proceeds  
10 along the lines and at the end of the line, the next line is started. In H.261, the order of the blocks is the same as described within a group of blocks, but in moving onto the next group of blocks, it is almost a zig-zag.

The present invention provides circuitry to deal  
15 with the latter affect. That is the way in which the address generation in the spatial decoder and the video formatter varies for H.261. This is accomplished whenever information is written into the DRAM. It is written with the knowledge of the aforementioned address generation sequence so the  
20 place where it is physically located in the RAM is exactly the same as if this had been an MPEG picture of the same size. Hence, all of the address generation circuitry for reading from the DRAM, for instance, when forming predictions, does not have to comprehend that it is H.261  
25 standard because the physical placement of the information in the memory is the same as it would have been if it had been in MPEG sequence. Thus, in all cases, only writing of data is affected.

In the Temporal Decoder, there is an abstraction for  
30 H.261 where the circuitry pretends something is different from what is actually occurring. That is, each group of blocks is conceptually stretched out so that instead of having a rectangle which is 11 x 3 macroblocks, the macroblocks are stretched out into a length of 33 blocks (see

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Figure 14c) group of blocks which is one macroblock high. By doing that, exactly the same counting mechanisms used on the Temporal Decoder for counting through the groups of blocks are also used for MPEG.

5           There is a correspondence in the way that the circuitry is designed between an H.261 group of blocks and an MPEG slice. When H.261 data is processed after the Start Code Detector, each group of blocks is preceded by a slice\_start\_code. The next group of blocks is preceded by  
10 the next slice\_start code. The counting that goes on inside the Temporal Decoder for counting through this structure pretends that it is a 33 macroblock-long group that is one macroblock high. This is sufficient, although the circuitry also counts every 11th interval. When it counts to the 11th  
15 macroblock or the 22nd macroblock, it resets some counters. This is accomplished by simple circuitry with another counter that counts up each macroblock, and when it gets to 11, it resets to zero. The microcode interrogates that and does that work. All the circuitry in the temporal decoder of the  
20 present invention is essentially independent of the compression standard with respect to the physical placement of the macroblocks.

In terms of multi-standard adaptability, there are a number of different tables and the circuitry selects the  
25 appropriate table for the appropriate standard at the appropriate time. Each standard has multiple tables; the circuitry selects from the set at any given time. Within any one standard, the circuitry selects one table at one time and another table another time. In a different standard, the  
30 circuitry selects a different set of tables. There is some intersection between those tables as indicated previously in the discussion of Figure 15. For example, one of the tables used in MPEG is also used in JPEG. The tables are not a completely isolated set. Figure 15 illustrates an H.261

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set, an MPEG set and a JPEG set. Note that there is a much greater overlap between the H.261 set and the MPEG set. They are quite common in the tables they utilize. There is a small overlap between MPEG and JPEG, and there is no overlap at all between H.261 and JPEG so that these standards have totally different sets of tables.

As previously indicated, most of the system units are compression standard independent. If a unit is standard independent, and such units need not remember what CODING\_STANDARD is being processed. All of the units that are standard dependent remember the compression standard as the CODING\_STANDARD token flows by them. When information encoded/decoded in a first coding standard is distributed through the machine, and a machine is changing standards, prior machines under microprocessor control would normally choose to perform in accordance with the H.261 compression standard. The MPU in such prior machines generates signals stating in multiple different places within the machine that the compression standard is changing. The MPU makes changes at different times and, in addition, may flush the pipeline through.

In accordance with the invention, by issuing a change of CODING\_STANDARD tokens at the Start Code Detector that is positioned as the first unit in the pipeline, this change of compression standard is readily handled. The token says a certain coding standard is beginning and that control information flows down the machine and configures all the other registers at the appropriate time. The MPU need not program each register.

The prediction token signals how to form predictions using the bits in the bitstream. Depending on which compression standard is operating, the circuitry translates the information that is found in the standard, i.e. from the bitstream into a prediction mode token. This processing is

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performed by the Huffman decoder and parser state machine, where it is easy to manipulate bits based on certain conditions. The Start Code Detector generates this prediction mode token. The token then flows down the machine to the circuitry of the Temporal Decoder, which is the device responsible for forming predictions. The circuitry of the spatial decoder interprets the token without having to know what standard it is operating in because the bits in it are invariant in the three different standards. The Spatial Decoder just does what it is told in response to that token. By having these tokens and using them appropriately, the design of other units in the machine is simplified. Although there may be some complications in the program, benefits are received in that some of the hard wired logic which would be difficult to design for multi-standards can be used here.

## 2. JPEG STILL PICTURE DECODING

As previously indicated, the present invention relates to signal decompression and, more particularly, to the decompression of an encoded video signal, irrespective of the compression standard employed.

One aspect of the present invention is to provide a first decoder circuit (the Spatial Decoder) to decode a first encoded signal (the JPEG encoded video signal) in combination with a second decoder circuit (the Temporal Decoder) to  
25 decode a first encoded signal (the MPEG or H.261 encoded video signal) in a pipeline processing system. The Temporal Decoder is not needed for JPEG decoding.

In this regard, the invention facilitates the decompression of a plurality of differently encoded signals through the use of a single pipeline decoder and decompression system. The decoding and decompression pipeline processor is organized on a unique and special configuration which allows the handling of the multi-standard

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With regard to JPEG decoding, a single Spatial Decoder with no off chip DRAM can rapidly decode baseline JPEG images. The Spatial Decoder supports all features of baseline JPEG encoding standards. However, the image size that can be decoded may be limited by the size of the output buffer provided. The Spatial Decoder circuit also includes a random access memory circuit, having machine-dependent, standard independent address generation circuits for handling the storage of information into the memories.

As previously, indicated the Temporal Decoder is not required to decode JPEG-encoded video. Accordingly, signals carried by DATA tokens pass directly through the Temporal Decoder without further processing when the Temporal Decoder is configured for a JPEG operation.

Another aspect of the present invention is to provide in the Spatial Decoder a pair of memory circuits, such as buffer memory circuits, for operating in combination with the Huffman decoder/video demultiplexor circuit (HD & VDM). A first buffer memory is positioned before the HD & VDM, and a second buffer memory is positioned after the HD & VDM. The HD & VDM decodes the bitstream from the binary ones and zeros that are in the standard encoded bitstream and turns such stream into numbers that are used downstream. The advantage of the two buffer system is for implementing a multi-standard decompression system. These two buffers, in combination with the identified implementation of the Huffman decoder, are described hereinafter in greater detail.

A still further aspect of the present multi-standard, decompression circuit is the combination of a Start Code Detector circuit positioned upstream of the first forward buffer operating in combination with the Huffman decoder. One advantage of this combination is increased flexibility in dealing with the input bitstream, particularly padding, which has to be added to the bitstream. The placement of these

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In addition, off chip DRAMs are used for decoding JPEG-  
5 encoded video pictures in real time. The size and speed of  
the buffers used with the DRAMs will depend on the video  
encoded data rates.

### 3. MOTION PICTURE DECOMPRESSION

30        Generally, the Temporal Decoder performs the processing between pictures either earlier and/or later in time with reference to the picture currently being decoded. The Temporal Decoder reintroduces information that is not encoded within the coded representation of the picture, because it is



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5       As previously mentioned, one important feature of the  
Temporal Decoder is to add picture information together from  
a selection of pictures which have arrived earlier or later  
than the picture under processing. When a picture is  
described in this context, it may mean any one of the  
10 following:

- 15    3.    Previously decoded pictures read from the DRAM; and
4.    The result of the spatial decoding, i.e., the extent  
     of data between a PICTURE\_START token and a  
     subsequent PICTURE END token.

20 Temporal Decoder, it is either displayed or written back into  
a picture memory location. This information is then kept for  
further reference to be used in processing another different  
coded data picture.

Re-ordering of the MPEG encoded pictures for visual  
25 display involves the possibility that a desired scrambled  
picture can be achieved by varying the re-ordering feature of  
the Temporal Decoder.

#### 4. RAM MEMORY MAP

The Spatial Decoder, Temporal Decoder and Video  
20 Formatter all use external DRAM. Preferably, the same DRAM  
is used for all three devices. While all three devices use  
DRAM, and all three devices use a DRAM interface in  
conjunction with an address generator, what each implements

5 In brief, the Spatial Decoder implements two FIFOs in the common DRAM. Referring again to Figure 11, one FIFO 54 is positioned before the Huffman decoder 56 and parser, and the other is positioned after the Huffman decoder and parser. The FIFOs are implemented in a relatively straightforward manner. For each FIFO, a particular portion of DRAM is set  
10 aside as the physical memory in which the FIFO will be implemented.

In brief, the Temporal Decoder of the present invention must be able to store two full pictures or frames of whatever encoding standard (MPEG or H.261) is specified. For simplicity, the physical memory in the DRAM into which the two frames are stored is split into two halves, with each half being dedicated (using appropriate pointers) to a particular one of the two pictures.

MPEG uses three different picture types: Intra (I), Predicted (P) and Bidirectionally interpolated (B). As previously mentioned, B pictures are based on predictions from two pictures. One picture is from the future and one from the past. I pictures require no further decoding by the Temporal Decoder, but must be stored in one of the two

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In contrast, H.261 makes predictions only from the picture just decoded. As each picture is decoded, it is written into one of the two picture buffers so it can be used in decoding the next picture. The only DRAM memory operations required are writing 8 x 8 blocks, and forming predictions with integer accuracy motion vectors.

In brief, the Video Formatter stores three frames or pictures. Three pictures need to be stored to accommodate such features as repeating or skipping pictures.

#### 5. BITSTREAM CHARACTERISTICS

Referring now particularly to the Spatial Decoder of the present invention, it is helpful to review the bitstream characteristics of the encoded datastream as these characteristics must be handled by the circuitry of the Spatial Decoder and the Temporal Decoder. For example, under one or more compression standards, the compression ratio of the standard is achieved by varying the number of bits that it uses to code the pictures of a picture. The number of bits can vary by a wide margin. Specifically, this means that the length of a bitstream used to encode a referenced picture of a picture might be identified as being one unit long, another picture might be a number of units long, while still a third picture could be a fraction of that unit.

None of the existing standards (MPEG 1.2, JPEG, H.261) define a way of ending a picture, the implication being that when the next picture starts, the current one has finished. Additionally, the standards (H.261 specifically) allow incomplete pictures to be generated by the encoder.

In accordance with the present invention, there is provided a way of indicating the end of a picture by using one of its tokens: PICTURE\_END. The still encoded picture data leaving the Start Code Detector consists of pictures starting with a PICTURE\_START token and ending with a

PICTURE\_END token, but still of widely varying length. There may be other information transmitted here (between the first and second picture), but it is known that the first picture has finished.

5       The data stream at the output of the Spatial Decoder consists of pictures, still with picture-starts and picture-ends, of the same length (number of bits) for a given sequence. The length of time between a picture-start and a picture-end may vary.

10       The Video Formatter takes these pictures of non-uniform time and displays them on a screen at a fixed picture rate determined by the type of display being driven. Different display rates are used throughout the world, e.g. PAL-NTSC television standards. This is accomplished by selectively  
15       dropping or repeating pictures in a manner which is unique. Ordinary "frame rate converters," e.g. 2-3 pulldown, operate with a fixed input picture rate, whereas the Video Formatter can handle a variable input picture rate.

#### 6. RECONFIGURABLE PROCESSING STAGE

20       Referring again to Figure 10, the reconfigurable processing stage (RPS) comprises a token decode circuit 33 which is employed to receive the tokens coming from a two wire interface 37 and input latches 34. The output of the token decode circuit 33 is applied to a processing unit 36  
25       over the two-wire interface 37 and an action identification circuit 39. The processing unit 36 is suitable for processing data under the control of the action identification circuit 39. After the processing is completed, the processing unit 36 connects such completed  
30       signals to the output, two-wire interface bus 40 through output latches 41.

      The action identification decode circuit 39 has an input from the token decode circuit 33 over the two-wire

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interface bus 40 and/or from memory circuits 43 and 44 over two-wire interface bus 46. The tokens from the token decode circuit 33 are applied simultaneously to the action identification circuit 39 and the processing unit 36. The action identification function as well as the RPS is described in further detail by tables and figures in a subsequent portion of this specification.

The functional block diagram in Figure 10 illustrates those stages shown in Figures 11, 12 and 13 which are not standard independent circuits. The data flows through the token decode circuit 33, through the processing unit 36 and onto the two-wire interface circuit 42 through the output latches 41. If the Control Token is recognized by the RPS, it is decoded in the token decode circuit 33 and appropriate action will be taken. If it is not recognized, it will be passed unchanged to the output two-wire interface 42 through the output circuit 41. The present invention operates as a pipeline processor having a two-wire interface for controlling the movement of control tokens through the pipeline. This feature of the invention is described in greater detail in the previously filed EPO patent application number 92306038.8.

In the present invention, the token decode circuit 33 is employed for identifying whether the token presently entering through the two-wire interface 42 is a DATA token or control token. In the event that the token being examined by the token decode circuit 33 is recognized, it is exited to the action identification circuit 39 with a proper index signal or flag signal indicating that action is to be taken. At the same time, the token decode circuit 33 provides a proper flag or index signal to the processing unit 36 to alert it to the presence of the token being handled by the action identification circuit 39.

Control tokens may also be processed.

A more detailed description of the various types of tokens usable in the present invention will be subsequently described hereinafter. For the purpose of this portion of the specification, it is sufficient to note that the address carried by the control token is decoded in the decoder 33 and is used to access registers contained within the action identification circuit 39. When the token being examined is a recognized control token, the action identification circuit 39 uses its reconfiguration state circuit for distributing the control signals throughout the state machine. As previously mentioned, this activates the state machine of the action identification decoder 39, which then reconfigures itself. For example, it may change coding standards. In this way, the action identification circuit 39 decodes the required action for handling the particular standard now passing through the state machine shown with reference to Figure 10.

Similarly, the processing unit 36 which is under the control of the action identification circuit 39 is now ready to process the information contained in the data fields of the DATA token when it is appropriate for this to occur. On many occasions, a control token arrives first, reconfigures the action identification circuit 39 and is immediately followed by a DATA token which is then processed by the processing unit 36. The control token exits the output latches circuit 41 over the output two-wire interface 42 immediately preceding the DATA token which has been processed within the processing unit 36.

In the present invention, the action identification circuit, 39, is a state machine holding history state. The registers, 43 and 44 hold information that has been decoded from the token decoder 33 and stored in these registers.



Such registers can be either on-chip or-off chip as needed. These plurality of state registers contain action information connected to the action identification currently being identified in the action identification circuit 39. This action information has been stored from previously decoded tokens and can affect the action that is selected. The connection 40 is going straight from the token decode 33 to the action identification block 39. This is intended to show that the action can also be affected by the token that is currently being processed by the token decode circuit 33.

In general, there is shown token decoding and data processing in accordance with the present invention. The data processing is performed as configured by the action identification circuit 39. The action is affected by a number of conditions and is affected by information generally derived from a previously decoded token or, more specifically, information stored from previously decoded tokens in registers 43 and 44, the current token under processing, and the state and history information that the action identification unit 39 has itself acquired. A distinction is thereby shown between Control tokens and DATA tokens.

In any RPS, some tokens are viewed by that RPS unit as being Control tokens in that they affect the operation of the RPS presumably at some subsequent time. Another set of tokens are viewed by the RPS as DATA tokens. Such DATA tokens contain information which is processed by the RPS in a way that is determined by the design of the particular circuitry, the tokens that have been previously decoded and the state of the action identification circuit 39. Although a particular RPS identifies a certain set of tokens for that particular RPS control and another set of tokens as data, that is the view of that particular RPS. Another RPS can have a different view of the same token. Some of the tokens



the stages of circuitry has the processing capability within it to be able to perform the necessary operations for each of the standards, and the control, as to which operations are to be performed at a given time, come as tokens. There is one processing element that differs between the different stages to provide this capability. In the state machine ROM of the parser, there are three separate entirely different programs, one for each of the standards that are dealt with. Which program is executed depends upon a CODING\_STANDARD token. In otherwords, each of these three programs has within it the ability to handle both decoding and the CODING\_STANDARD standard token. When each of these programs sees which coding standard, is to be decoded next, they literally jump to the start address in the microcode ROM for that particular program. This is how stages deal with multi-standardness.

Two things are affected by the different standards. First, it affects what pattern of bits in the bitstream are recognized as a start-code or a marker code in order to reconfigure the shift register to detect the length of the start marker code. Second, there is a piece of information in the microcode that denotes what that start or marker code means. Recall that the coding of bits differs between the three standards. Accordingly, the microcode looks up in a table, specific to that compressor standard, something that is independent of the standard, i.e., a type of token that represents the incoming codes. This token is typically independent of the standard since in most cases, each of the various standards provide a certain code that will produce it.

The inverse quantizer 79 has a mathematical capability. The quantizer multiplies and adds, and has the ability to do all three compression standards which are configured by parameters. For example, a flag bit in the ROM in control tells the inverse quantizer whether or not to add

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In a similar sense the Huffman decoder 56 has a number of tables within it, some for JPEG, some for MPEG and some for H.261. The majority of those tables, in fact, will service more than one of those compression standards. Which tables are used depends on the syntax of the standard. The Huffman decoder works by receiving a command from the state machine which tells it which of the tables to use. Accordingly, the Huffman decoder does not itself directly have a piece of state going into it, which is remembered and which says what coding it is performing. Rather, it is the combination of the parser state machine and Huffman decoder together that contain information within them.

Regarding the Spatial Decoder of the present invention, the address generation is modified and is similar to that shown in Figure 10, in that a number of pieces of information are decoded from tokens, such as the coding standard. The coding standard and additional information as well, is recorded in the registers and that affects the progress of the address generator state machine as it steps through and counts the macroblocks in the system, one after the other. The last stage would be the prediction filter (Figure 17) which operates in one of two modes, either H.261 or MPEG and are easily identified.

## 7. MULTI-STANDARD CODING

The system of the present invention also provides a combination of the standard-independent indices generation circuits, which are strategically placed throughout the system in combination with the token decode circuits. For example, the system is employed for specifically decoding either the H.261 video standard, or the MPEG video standard or the JPEG video standard. These three compression coding standards specify similar processes to be done on the arriving data, but the structure of the datastreams is different. As previously discussed, it is one of the functions of the Start Code Detector to detect MPEG start-codes, H.261 start-codes, and JPEG marker codes, and convert them all into a form, i.e., a control token which includes a token stream embodying the current coding standard. The control tokens are passed through the pipeline processor, and are used, i.e., decoded, in the state machines to which they are relevant, and are passed through other state machines to which the tokens are not relevant. In this regard, the DATA Tokens are treated in the same fashion, insofar as they are processed only in the state machines that are configurable by the control tokens into processing such DATA Tokens. In the remaining state machines, they pass through unchanged.

More specifically, a control token in accordance with the present invention, can consist of more than one word in the token. In that case, a bit known as the extension bit is set specifying the use of additional words in the token for carrying additional information. Certain of these additional control bits contain indices indicating information for use in corresponding state machines to create a set of standard-independent indices signals. The remaining portions of the token are used to indicate and identify the internal processing control function which is standard for all of the datastreams passing through the pipeline processor. In one

form of the invention, the token extension is used to carry the current coding standard which is decoded by the relative token decode circuits distributed throughout the machine, and is used to reconfigure the action identification circuit 39 of stages throughout the machine wherever it is appropriate to operate under a new coding standard. Additionally, the token decode circuit can indicate whether a control token is related to one of the selected standards which the circuit was designed to handle.

10 More specifically, an MPEG start code and a JPEG marker are followed by an 8 bit value. The H.261 start code is followed by a 4 bit value. In this context, the Start Code Detector 51, by detecting either an MPEG start-code or a JPEG marker, indicates that the following 8 bits contain the value  
15 associated with the start-code. Independently, it can then create a signal which indicates that it is either an MPEG start code or a JPEG marker and not an H.261 start code. In this first instance, the 8 bit value is entered into a decode circuit, part of which creates a signal indicating the index  
20 and flag which is used within the current circuit for handling the tokens passing through the circuit. This is also used to insert portions of the control token which will be looked at thereafter to determine which standard is being handled. In this sense, the control token contains a portion  
25 indicating that it is related to an MPEG standard, as well as a portion which indicates what type of operation should be performed on the accompanying data. As previously discussed, this information is utilized in the system to reconfigure the processing stage used to perform the function required by the  
30 various standards created for that purpose.

For example, with reference to the H.261 start code, it is associated with a 4 bit value which follows immediately after the start code. The Start Code Detector passes this value into the token generator state machine. The value is

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applied to an 8 bit decoder which produces a 3 bit start number. The start number is employed to identify the picture-start of a picture number as indicated by the value.

The system also includes a multi-stage parallel processing pipeline operating under the principles of the two-wire interface previously described. Each of the stages comprises a machine generally taking the form illustrated in Figure 10. The token decode circuit 33 is employed to direct the token presently entering the state machine into the action identification circuit 39 or the processing unit 36, as appropriate. The processing unit has been previously reconfigured by the next previous control token into the form needed for handling the current coding standard, which is now entering the processing stage and carried by the next DATA token. Further, in accordance with this aspect of the invention, the succeeding state machines in the processing pipeline can be functioning under one coding standard, i.e., H.261, while a previous stage can be operating under a separate standard, such as MPEG. The same two-wire interface is used for carrying both the control tokens and the DATA Tokens.

The system of the present invention also utilizes control tokens required to decode a number of coding standards with a fixed number of reconfigurable processing stages. More specifically, the PICTURE\_END control token is employed because it is important to have an indication of when a picture actually ends. Accordingly, in designing a multi-standard machine, it is necessary to create additional control tokens within the multi-standard pipeline processing machine which will then indicate which one of the standard decoding techniques to use. Such a control token is the PICTURE\_END token. This PICTURE\_END token is used to indicate that the current picture has finished, to force the buffers to be flushed, and to push the current picture

through the decoder to the display.

#### 8. MULTI-STANDARD PROCESSING CIRCUIT - SECOND MODE OF OPERATION

A compression standard-dependent circuit, in the form of  
5 the previously described Start Code Detector, is suitably  
interconnected to a compression standard-independent circuit  
over an appropriate bus. The standard-dependent circuit is  
connected to a combination dependent-independent circuit over  
the same bus and an additional bus. The standard-independent  
10 circuit applies additional input to the standard dependent-  
independent circuit, while the latter provides information  
back to the standard-independent circuit. Information from  
the standard-independent circuit is applied to the output  
over another suitable bus. Table 600 illustrates that the  
15 multiple standards applied as the input to the standard-  
dependent Start Code Detector 51 include certain bit streams  
which have standard-dependent meanings within each encoded  
bit stream.

#### 9. START-CODE DETECTOR

20 As previously indicated the Start Code Detector, in  
accordance with the present invention, is capable of taking  
MPEG, JPEG and H.261 bit streams and generating from them a  
sequence of proprietary tokens which are meaningful to the  
rest of the decoder. As an example of how multi-standard  
25 decoding is achieved, the MPEG (1 and 2) picture\_start\_code,  
the H.261 picture\_start\_code and the JPEG start\_of\_scan (SOS)  
marker are treated as equivalent by the Start Code Detector,  
and all will generate an internal PICTURE\_START token. In a  
similar way, the MPEG sequence\_start\_code and the JPEG SOI  
30 (start\_of\_image) marker both generate a machine  
sequence\_start\_token. The H.261 standard, however, has no  
equivalent start code. Accordingly, the Start Code Detector,

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None of the above described images are directly used other than in the SCD. Rather, a machine PICTURE\_START token, for example, has been deemed to be equivalent to the PICTURE\_START images contained in the bit stream. Furthermore, it must be borne in mind that the machine PICTURE\_START by itself, is not a direct image of the PICTURE\_START in the standard. Rather, it is a control token which is used in combination with other control tokens to provide standard-independent decoding which emulates the operation of the images in each of the compression coding standards. The combination of control tokens in combination with the reconfiguration of circuits, in accordance with the information carried by control tokens, is unique in and of itself, as well as in further combination with indices and/or flags generated by the token decode circuit portion of a respective state machine. A typical reconfigurable state machine will be described subsequently.

Referring again to Table 600, there are shown the names of a group of standard images in the left column. In the right column there are shown the machine dependent control tokens used in the emulation of the standard encoded signal which is present or not used in the standard image.

With reference to Table 600, it can be seen that a machine sequence\_start signal is generated by the Start Code Detector, as previously described, when it decodes any one of the standard signals indicated in Table 600. The Start Code Detector creates sequence\_start, group\_start, sequence\_end, slice\_start, user-data, extra-data and PICTURE\_START tokens for application to the two-wire interface which is used throughout the system. Each of the stages which operate in conjunction with these control tokens are configured by the contents of the tokens, or are configured by indices created

by contents of the tokens, and are prepared to handle data which is expected to be received when the picture DATA Token arrives at that station.

As previously described, one of the compression standards, such as H.261, does not have a sequence\_start image in its data stream, nor does it have a PICTURE\_END image in its data stream. The Start Code Detector indicates the PICTURE\_END point in the incoming bit stream and creates a PICTURE\_END token. In this regard, the system of the present invention is intended to carry data words that are fully packed to contain a bit of information in each of the register positions selected for use in the practice of the present invention. To this end, 15 bits have been selected as the number of bits which are passed between two start codes. Of course, it will be appreciated by one of ordinary skill in the art, that a selection can be made to include either greater or fewer than 15 bits. In other words, all 15 bits of a data word being passed from the Start Code Detector into the DRAM interface are required for proper operation. Accordingly, the Start Code Detector creates extra bits, called padding, which it inserts into the last word of a DATA Token. For purposes of illustration 15 data bits has been selected.

To perform the Padding operation, in accordance with the present invention, binary 0 followed by a number of binary 1's are automatically inserted to complete the 15 bit data word. This data is then passed through the coded data buffer and presented to the Huffman decoder, which removes the padding. Thus, an arbitrary number of bits can be passed through a buffer of fixed size and width.

In one embodiment, a slice\_start control token is used to identify a slice of the picture. A slice\_start control token is employed to segment the picture into smaller regions. The size of the region is chosen by the encoder.

and the Start Code Detector identifies this unique pattern of the slice\_start code in order for the machine-dependent state stages, located downstream from the Start Code Detector, to segment the picture being received into smaller regions. The size of the region is chosen by the encoder, recognized by the Start Code Detector and used by the recombination circuitry and control tokens to decompress the encoded picture. The slice\_start\_codes are principally used for error recovery.

The start codes provide a unique method of starting up the decoder, and this will subsequently be described in further detail. There are a number of advantages in placing the Start Code Detector before the coded data buffer, as opposed to placing the Start Code Detector after the coded data buffer and before the Huffman decoder and video demultiplexor. Locating the Start Code Detector before the first buffer allows it to 1) assemble the tokens, 2) decode the standard control signals, such as start codes, 3) pad the bitstream before the data goes into the buffer, and 4) create the proper sequence of control tokens to empty the buffers, pushing the available data from the buffers into the Huffman Decoder.

Most of the control token output by the Start Code Detector directly reflect syntactic elements of the various picture and video coding standards. The Start Code Detector converts the syntactic elements into control tokens. In addition to these natural tokens, some unique and/or machine-dependent tokens are generated. The unique tokens include those tokens which have been specifically designed for use with the system of the present invention which are unique in and of themselves, and are employed for aiding in the multi-standard nature of the present invention. Examples of such unique tokens include PICTURE\_END and CODING\_STANDARD.

Tokens are also introduced to remove some of the

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standard-dependent coded data with reference to the Start Code Detector.

Each of the standard compression encoding systems employs a unique start code configuration or image which has been selected to identify that particular compression specification. Each of the start codes also carries with it a start code value. The start code value is employed to identify within the language of the standard the type of operation that the start code is associated with. In the multi-standard decoder of the present invention, the compatibility is based upon the control token and DATA token configuration as previously described. Index signals, including flag signals, are circuit-generated within each state machine, and are described hereinafter as appropriate.

The start and/or marker codes contained in the standards, as well as other standard words as opposed to data words, are sometimes identified as images to avoid confusion with the use of code and/or machine-dependent codes to refer to the contents of control and/or DATA tokens used in the machine. Also, the term start code is often used as a generic term to refer to JPEG marker codes as well as MPEG and H.261 start codes. Marker codes and start codes serve the same purpose. Also, the term "flush" is used both to refer to the FLUSH token, and as a verb, for example when referring to flushing the Start Code Detector shift registers (including the signal "flushed"). To avoid confusion, the FLUSH token is always written in upper case. All other uses of the term (verb or noun) are in lower case.

The standard-dependent coded input picture input stream comprises data and start images of varying lengths. The start images carry with them a value telling the user what operation is to be performed on the data which immediately follows according to the standard. However, in the multi-standard pipeline processing system of the present invention,

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where compatibility is required for multiple standards, the system has been optimized for handling all functions in all standards. Accordingly, in many situations, unique start control tokens must be created which are compatible not only  
 5 with the values contained in the values of the encoded signal standard image, but which are also capable of controlling the various stages to emulate the operation of the standard as represented by specified parameters for each standard which are well known in the art. All such standards are  
 10 incorporated by reference into this specification.

It is important to understand the relationship between tokens which, alone or in combination with other control tokens, emulate the nondata information contained in the standard bit stream. A separate set of index signals,  
 15 including flag signals, are generated by each state machine to handle some of the processing within that state machine. Values carried in the standards can be used to access machine dependent control signals to emulate the handling of the standard data and non-data signals. For example, the  
 20 slice\_start token is a two word token, and it is then entered onto the two wire interface as previously described.

The data input to the system of the present invention may be a data source from any suitable data source such as disk, tape, etc., the data source providing 8 bit data to the  
 25 first functional stage in the Spatial Decoder, the Start Code Detector 51 (Figure 11). The Start Code Detector includes three shift registers; the first shift register is 8 bits wide, the next is 24 bits wide, and the next is 15 bits wide. Each of the registers is part of the two-wire interface. The  
 30 data from the data source is loaded into the first register as a single 8 bit byte during one timing cycle. Thereafter, the contents of the first shift register is shifted one bit at a time into the decode (second) shift register. After 24 cycles, the 24 bit register is full.

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Every 8 cycles, the 8 bit bytes are loaded into the first shift register. Each byte is loaded into the value shift register 221 (Figure 20), and 8 additional cycles are used to empty it and load the shift register 231. Eight  
 5 cycles are used to empty it, so after three of those operations or 24 cycles, there are still three bytes in the 24 bit register. The value decode shift register 230 is still empty.

Assuming that there is now a PICTURE\_START word in the  
 10 24 bit shift register, the detect cycle recognizes the PICTURE\_START code pattern and provides a start signal as its output. Once the detector has detected a start, the byte following it is the value associated with that start code, and this is currently sitting in the value register 221.

15 Since the contents of the detect shift register has been identified as a start code, its contents must be removed from the two wire interface to ensure that no further processing takes place using these 3 bytes. The decode register is emptied, and the value decode shift register 230 waits for  
 20 the value to be shifted all the way over to such register.

The contents now of the low order bit positions of the value decode shift register contains a value associated with the PICTURE\_START. The Spatial Decoder equivalent to the standard PICTURE\_START signal is referred to as the SD  
 25 PICTURE\_START signal. The SD PICTURE\_START signal itself is going to now be contained in the token header, and the value is going to be contained in the extension word to the token header.

#### 10. . TOKENS

30 In the practice of the present invention, a token is a universal adaptation unit in the form of an interactive interfacing messenger package for control and/or data functions and is adapted for use with a reconfigurable

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processing stage (RPS) which is a stage, which in response to a recognized token, reconfigures itself to perform various operations.

5 Tokens may be either position dependent or position independent upon the processing stages for performance of various functions. Tokens may also be metamorphic in that they can be altered by a processing stage and then passed down the pipeline for performance of further functions. Tokens may interact with all or less than all of the stages and in this regard may interact with adjacent and/or non-adjacent stages. Tokens may be position dependent for some functions and position independent for other functions, and the specific interaction with a stage may be conditioned by the previous processing history of a stage.

10 A PICTURE\_END token is a way of signalling the end of a picture in a multi-standard decoder.

15 A multi-standard token is a way of mapping MPEG, JPEG and H.261 data streams onto a single decoder using a mixture of standard dependent and standard independent hardware and control tokens.

20 A SEARCH\_MODE token is a technique for searching MPEG, JPEG and H.261 data streams which allows random access and enhanced error recovery.

25 A STOP\_AFTER\_PICTURE token is a method of achieving a clear end to decoding which signals the end of a picture and clears the decoder pipeline, i.e., channel change.

Furthermore, padding a token is a way of passing an arbitrary number of bits through a fixed size, fixed width buffer.

30 The present invention is directed to a pipeline processing system which has a variable configuration which uses tokens and a two-wire system. The use of control tokens and DATA Tokens in combination with a two-wire system facilitates a multi-standard system capable of having

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extended operating capabilities as compared with those systems which do not use control tokens.

The control tokens are generated by circuitry within the decoder processor and emulate the operation of a number of different type standard-dependent signals passing into the serial pipeline processor for handling. The technique used is to study all the parameters of the multi-standards that are selected for processing by the serial processor and noting 1) their similarities, 2) their dissimilarities, 3) their needs and requirements and 4) selecting the correct token function to effectively process all of the standard signals sent into the serial processor. The functions of the tokens are to emulate the standards. A control token function is used partially as an emulation/translation between the standard dependent signals and as an element to transmit control information through the pipeline processor.

In prior art system, a dedicated machine is designed according to well-known techniques to identify the standard and then set up dedicated circuitry by way of microprocessor interfaces. Signals from the microprocessor are used to control the flow of data through the dedicated downstream components. The selection, timing and organization of this decompression function is under the control of fixed logic circuitry as assisted by signals coming from the microprocessor.

In contrast, the system of the present invention configures the downstream functional stages under the control of the control tokens. An option is provided for obtaining needed and/or alternative control from the MPU.

The tokens provide and make a sensible format for communicating information through the decompression circuit pipeline processor. In the design selected hereinafter and used in the preferred embodiment, each word of a token is a minimum of 8 bits wide, and a single token can extend over

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one or more words. The width of the token is changeable and can be selected as any number of bits. An extension bit indicates whether a token is extended beyond the current word, i.e., if it is set to binary one in all words of a token, except the last word of a token. If the first word of a token has an extension bit of zero, this indicates that the token is only one word long.

Each token is identified by an address field that starts at bit 7 of the first word of the token. The address field is variable in length and can potentially extend over multiple words. In a preferred embodiment, the address is no longer than 8 bits long. However, this is not a limitation on the invention, but on the magnitude of the processing steps elected to be accomplished by use of these tokens. It is to be noted under the extension bit identification label that the extension bit in words 1 and 2 is a 1, signifying that additional words will be coming thereafter. The extension bit in word 3 is a zero, therefore indicating the end of that token.

20 The token is also capable of variable bit length. For example, there are 9 bits in the token word plus the extension bit for a total of 10 bits. In the design of the present invention, output buses are of variable width. The output from the Spatial Decoder is 9 bits wide, or 10 bits  
25 wide when the extension bit is included. In a preferred embodiment, the only token that takes advantage of these extra bits is the DATA token; all other tokens ignore this extra bit. It should be understood that this is not a limitation, but only an implementation.

20 Through the use of the DATA token and control token configuration, it is possible to vary the length of the data being carried by these DATA tokens in the sense of the number of bits in one word. For example, it has been discussed that data bits in word of a DATA Token can be combined with the

data bits in another word of the same DATA token to form an 11 bit or 10 bit address for use in accessing the random access memories used throughout this serial decompression processor. This provides an additional degree of variability  
5 that facilitates a broad range of versatility.

As previously described, the DATA token carries data from one processing stage to the next. Consequently, the characteristics of this token change as it passes through the decoder. For example, at the input to the Spatial Decoder,  
10 DATA Tokens carry bit serial coded video data packed into 3 bit words. Here, there is no limit to the length of each token. However, to illustrate the versatility of this aspect of the invention (at the output of the Spatial Decoder circuit), each DATA Token carries exactly 64 words and each  
15 word is 9 bits wide. More specifically, the standard encoding signal allows for different length messages to encode different intensities and details of pictures. The first picture of a group normally carries the longest number of data bits because it needs to provide the most information  
20 to the processing unit so that it can start the decompression with as much information as possible. Words which follow later are typically shorter in length because they contain the difference signals comparing the first word with reference to the second position on the scan information  
25 field.

The words are interspersed with each other, as required by the standard encoding system, so that variable amounts of data are provided into the input of the Spatial Decoder. However, after the Spatial Decoder has functioned, the  
30 information is provided at its output at a picture format rate suitable for display on a screen. The output rate in terms of time of the spatial decoder may vary in order to interface with various display systems throughout the world, such as NTSC, PAL and SECAM. The video formatter converts

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this variable picture rate to a constant picture rate suitable for display. However, the picture data is still carried by DATA tokens consisting of 64 words.

## 11. DRAM INTERFACE

5       A single high performance, configurable DRAM interface  
is used on each of the 3 decoder chips. In general, the DRAM  
interface on each chip is substantially the same; however,  
the interfaces differ from one to another in how they handle  
channel priorities. This interface is designed to directly  
10       drive the external DRAMs used by the Spatial Decoder, the  
Temporal Decoder and the Video Formatter. Typically, no  
external logic, buffers or components will be required to  
connect the DRAM interface to the DRAMs in those systems.

In accordance with the present invention, the interface is  
15 configurable in two ways:

1. The detailed timing of the interface can be configured to accommodate a variety of different DRAM types.
2. The width of the data interface to the DRAM can be configured to provide a cost/performance trade off for different applications.

In general, the DRAM interface is a standard-independent block implemented on each of the three chips in the system. Again, these are the Spatial Decoder, Temporal Decoder and video formatter. Referring again to Figures 11, 12 and 13, these figures show block diagrams that depict the relationship between the DRAM interface, and the remaining blocks of the Spatial Decoder, Temporal Decoder and video formatter, respectively. On each chip, the DRAM interface connects the chip to an external DRAM. External DRAM is used because, at present, it is not practical to fabricate on chip the relatively large amount of DRAM needed. Note: each chip has its own external DRAM and its own DRAM interface.

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swing buffer.

In the present invention, each of the chips has four swing buffers, but the function of these swing buffers is different in each case. In the spatial decoder, one swing buffer is used to transfer coded data to the DRAM, another to read coded data from the DRAM, the third to transfer tokenized data to the DRAM and the fourth to read tokenized data from the DRAM. In the Temporal Decoder, however, one swing buffer is used to write intra or predicted picture data to the DRAM, the second to read intra or predicted data from the DRAM and the other two are used to read forward and backward prediction data. In the video formatter, one swing buffer is used to transfer data to the DRAM and the other three are used to read data from the DRAM, one for each of luminance (Y) and the red and blue color difference data (Cr and Cb, respectively).

The following section describes the operation of a hypothetical DRAM interface which has one write swing buffer and one read swing buffer. Essentially, this is the same as the operation of the Spatial Decoder's DRAM interface. The operation is illustrated in Figure 23.

Figure 23 illustrates that the control interfaces between the address generator 301, the DRAM interface 302, and the remaining stages of the chip which pass data are all two wire interfaces. The address generator 301 may either generate addresses as the result of receiving control tokens, or it may merely generate a fixed sequence of addresses (e.g., for the FIFO buffers of the Spatial Decoder). The DRAM interface treats the two wire interfaces associated with the address generator 301 in a special way. Instead of keeping the accept line high when it is ready to receive an address, it waits for the address generator to supply a valid address, processes that address and then sets the accept line high for one clock period. Thus, it implements a

request/acknowledge (REQ/ACK) protocol.

5 A unique feature of the DRAM interface 302 is its ability to communicate independently with the address generator 301 and with the stages that provide or accept the data. For example, the address generator may generate an address associated with the data in the write swing buffer (Figure 24), but no action will be taken until the write swing buffer signals that there is a block of data ready to be written to the external DRAM. Similarly, the write swing  
10 buffer may contain a block of data which is ready to be written to the external DRAM, but no action is taken until an address is supplied on the appropriate bus from the address generator 301. Further, once one of the RAMs in the write swing buffer has been filled with data, the other may be  
15 completely filled and "swung" to the DRAM interface side before the data input is stalled (the two-wire interface accept signal set low).

In understanding the operation of the DRAM interface 302 of the present invention, it is important to note that in a  
20 properly configured system, the DRAM interface will be able to transfer data between the swing buffers and the external DRAM 303 at least as fast as the sum of all the average data rates between the swing buffers and the rest of the chip.

Each DRAM interface 302 determines which swing buffer it  
25 will service next. In general, this will either be a "round robin" (i.e., the next serviced swing buffer is the next available swing buffer which has least recently had a turn), or a priority encoder, (i.e., in which some swing buffers have a higher priority than others). In both cases, an  
30 additional request will come from a refresh request generator which has a higher priority than all the other requests. The refresh request is generated from a refresh counter which can be programmed via the microprocessor interface.

Referring now to Figure 24, there is shown a block

diagram of a write swing buffer. The write swing buffer interface includes two blocks of RAM, RAM1 311 and RAM2 312. As discussed further herein, data is written into RAM1 311 and RAM2 312 from the previous stage, under the control of the write address 313 and control 314. From RAM1 311 and RAM2 312, the data is written into DRAM 515. When writing data into DRAM 315, the DRAM row address is provided by the address generator, and the column address is provided by the write address and control, as described further herein. In operation, valid data is presented at the input 316 (data in). Typically, the data is received from the previous stage. As each piece of data is accepted by the DRAM interface, it is written into RAM1 311 and the write address control increments the RAM1 address to allow the next piece of data to be written into RAM1. Data continues to be written into RAM1 311 until either there is no more data, or RAM1 is full. When RAM1 311 is full, the input side gives up control and sends a signal to the read side to indicate that RAM1 is now ready to be read. This signal passes between two asynchronous clock regimes and, therefore, passes through three synchronizing flip flops.

Provided RAM2 312 is empty, the next item of data to arrive on the input side is written into RAM2. Otherwise, this occurs when RAM2 312 has emptied. When the round robin or priority encoder (depending on which is used by the particular chip) indicates that it is now the turn of this swing buffer to be read, the DRAM interface reads the contents of RAM1 311 and writes them to the external DRAM 315. A signal is then sent back across the asynchronous interface, to indicate that RAM1 311 is now ready to be filled again.

If the DRAM interface empties RAM1 311 and "swings" it before the input side has filled RAM2 312, then data can be

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accepted by the swing buffer continually. Otherwise, when RAM2 is filled, the swing buffer will set its accept single low until RAM1 has been "swung" back for use by the input side.

5       The operation of a read swing buffer, in accordance with the present invention, is similar, but with the input and output data busses reversed.

10       The DRAM interface of the present invention is designed to maximize the available memory bandwidth. Each 8x8 block of data is stored in the same DRAM page. In this way, full use can be made of DRAM fast page access modes, where one row address is supplied followed by many column addresses. In particular, row addresses are supplied by the address generator, while column addresses are supplied by the DRAM interface, as discussed further below.

15       In addition, the facility is provided to allow the data bus to the external DRAM to be 8, 16 or 32 bits wide. Accordingly, the amount of DRAM used can be matched to the size and bandwidth requirements of the particular application.

20       In this example (which is exactly how the DRAM interface on the Spatial Decoder works) the address generator provides the DRAM interface with block addresses for each of the read and write swing buffers. This address is used as the row address for the DRAM. The six bits of column address are supplied by the DRAM interface itself, and these bits are also used as the address for the swing buffer RAM. The data bus to the swing buffers is 32 bits wide. Hence, if the bus width to the external DRAM is less than 32 bits, two or four external DRAM accesses must be made before the next word is read from a write swing buffer or the next word is written to a read swing buffer (read and write refer to the direction of transfer relative to the external DRAM).

25       The situation is more complex in the case of the

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Temporal Decoder and the Video Formatter. The Temporal Decoder's addressing is more complex because of its predictive aspects as discussed further in this section. The video formatter's addressing is more complex because of multiple video output standard aspects, as discussed further in the sections relating to the video formatter.

As mentioned previously, the Temporal Decoder has four swing buffers: two are used to read and write decoded intra and predicted (I and P) picture data. These operate as described above. The other two are used to receive prediction data. These buffers are more interesting.

In general, prediction data will be offset from the position of the block being processed as specified in the motion vectors in x and y. Thus, the block of data to be retrieved will not generally correspond to the block boundaries of the data as it was encoded (and written into the DRAM). This is illustrated in Figure 25, where the shaded area represents the block that is being formed whereas the dotted outline represents the block from which it is being predicted. The address generator converts the address specified by the motion vectors to a block offset (a whole number of blocks), as shown by the big arrow, and a pixel offset, as shown by the little arrow.

In the address generator, the frame pointer, base block address and vector offset are added to form the address of the block to be retrieved from the DRAM. If the pixel offset is zero, only one request is generated. If there is an offset in either the x or y dimension then two requests are generated, i.e., the original block address and the one immediately below. With an offset in both x and y, four requests are generated. For each block which is to be retrieved, the address generator calculates start and stop addresses which is best illustrated by an example.

Consider a pixel offset of (1,1), as illustrated by the

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Consider block A. At the start of reading, the swing

buffer address register is loaded with the inverse of the stop value. The y inverse stop value forms the 3 MSBs and the x inverse stop value forms the 3 LSB. In this case, while the DRAM interface is reading address 9 in the external  
 5 DRAM, the swing buffer address is zero. The swing buffer address register is then incremented as the external DRAM address register is incremented, as consistent with proper prediction addressing.

The discussion so far has centered on an 8 bit DRAM  
 10 interface. In the case of a 16 or 32 bit interface, a few minor modifications must be made. First, the pixel offset vector must be "clipped" so that it points to a 16 or 32 bit boundary. In the example we have been using, for block A, the first DRAM read will point to address 0, and data in  
 15 addresses 0 through 3 will be read. Second, the unwanted data must be discarded. This is performed by writing all the data into the swing buffer (which must now be physically larger than was necessary in the 8 bit case) and reading with an offset. When performing MPEG half-pel interpolation, 9  
 20 bytes in x and/or y must be read from the DRAM interface. In this case, the address generator provides the appropriate start and stop addresses. Some additional logic in the DRAM interface is used, but there is no fundamental change in the way the DRAM interface operates.

25 The final point to note about the Temporal Decoder DRAM interface of the present invention, is that additional information must be provided to the prediction filters to indicate what processing is required on the data. This consists of the following:

- 30 a "last byte" signal indicating the last byte of a transfer (of 64, 72 or 81 bytes);  
 an H.261 flag;  
 a bidirectional prediction flag;  
 two bits to indicate the block's dimensions (8 or 9 bytes)

in x and y); and

a two bit number to indicate the order of the blocks.

The last byte flag can be generated as the data is read out of the swing buffer. The other signals are derived from the address generator and are piped through the DRAM interface so that they are associated with the correct block of data as it is read out of the swing buffer by the prediction filter block.

In the Video Formatter, data is written into the external DRAM in blocks, but is read out in raster order. Writing is exactly the same as already described for the Spatial Decoder, but reading is a little more complex.

The data in the Video Formatter, external DRAM is organized so that at least 8 blocks of data fit into a single page. These 8 blocks are 8 consecutive horizontal blocks. When rasterizing, 8 bytes need to be read out of each of 8 consecutive blocks and written into the swing buffer (i.e., the same row in each of the 8 blocks).

Considering the top row (and assuming a byte-wide interface), the x address (the three LSBS) is set to zero, as is the y address (3 MSBS). The x address is then incremented as each of the first 8 bytes are read out. At this point, the top part of the address (bit 6 and above - LSB = bit 0) is incremented and the x address (3 LSBS) is reset to zero. This process is repeated until 64 bytes have been read. With a 16 or 32 bit wide interface to the external DRAM the x address is merely incremented by two or four, respectively, instead of by one.

In the present invention, the address generator can  
20 signal to the DRAM interface that less than 64 bytes should  
be read (this may be required at the beginning or end of a  
raster line), although a multiple of 8 bytes is always read.  
This is achieved by using start and stop values. The start  
value is used for the top part of the address (bit 6 and

above), and the stop value is compared with the start value to generate the signal which indicates when reading should stop.

The DRAM interface timing block in the present invention  
 5 uses timing chains to place the edges of the DRAM signals to a precision of a quarter of the system clock period. Two quadrature clocks from the phase locked loop are used. These are combined to form a notional 2x clock. Any one chain is then made from two shift registers in parallel, on opposite  
 10 phases of the 2x clock.

First of all, there is one chain for the page start cycle and another for the read/write/refresh cycles. The length of each cycle is programmable via the microprocessor interface, after which the page start chain has a fixed  
 15 length, and the cycle chain's length changes as appropriate during a page start.

On reset, the chains are cleared and a pulse is created. The pulse travels along the chains and is directed by the state information from the DRAM interface. The pulse  
 20 generates the DRAM interface clock. Each DRAM interface clock period corresponds to one cycle of the DRAM, consequently, as the DRAM cycles have different lengths, the DRAM interface clock is not at a constant rate.

Moreover, additional timing chains combine the pulse  
 25 from the above chains with the information from the DRAM interface to generate the output strobes and enables such as notcas, notras, notwe, notbe.

## 12. PREDICTION FILTERS

Referring again to Figures 12, 17, 18, and more  
 30 particularly to Figure 12, there is shown a block diagram of the Temporal Decoder. This includes the prediction filter. The relationship between the prediction filter and the rest of the elements of the temporal decoder is shown in greater

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to perform no filtering at all in JPEG mode. As with many other reconfigurable aspects of the three chip system, the prediction filter is reconfigured by means of tokens. Tokens are also used to inform the address generator of the particular mode of operation. In this way, the address generator can supply the prediction filter with the addresses of the needed data, which varies significantly between MPEG and JPEG.

### 13. ACCESSING REGISTERS

Most registers in the microprocessor interface (MPI) can only be modified if the stage with which they are associated is stopped. Accordingly, groups of registers will typically be associated with an access register. The value zero in an access register indicates that the group of registers associated with that particular access register should not be modified. Writing 1 to an access register requests that a stage be stopped. The stage may not stop immediately, however, so the stages access register will hold the value, zero, until it is stopped.

Any user software associated with the MPI and used to perform functions by way of the MPI should wait "after writing a 1 to a request access register" until 1 is read from the access register. If a user writes a value to a configuration register while its access register is set to zero, the results are undefined.

### 14. MICRO-PROCESSOR INTERFACE

A standard byte wide micro-processor interface (MPI) is used on all circuits with in the Spatial Decoder and Temporal Decoder. The MPI operates asynchronously with various Spatial and Temporal Decoder clocks. Referring to Table A.6.1 of the subsequent further detailed description, there is shown the various MPI signals that



The DC operating conditions can be seen with reference to Table A.6.3. Here the column headings are the same as with reference to Table A.6.2. The DC electrical characteristics are shown with reference to Table A.6.4 and carry the same column headings as depicted in Tables A.6.2 and A.6.3.

The AC characteristics of the MPI read timing diagrams are shown with reference to Figure 54. Each line of the Figure is labelled with a corresponding signal name and the timing is given in nano-seconds. The full microprocessor interface read timing characteristics are shown with reference to Table A.6.5. The column entitled Number is used to indicate the signal corresponding to the name of that signal as set forth in the characteristic column. The columns identified by MIN and MAX provide the minimum length of time that the signal is present the maximum amount of time that this signal is available. The Units column gives the units of measurement used to describe the signals.

## The general description of the MPI write timing diagrams



described. Each of the functional blocks is arranged to operate according to the state machine configuration shown with reference to Figure 10.

In general, the PICTURE\_END function in accordance with the invention begins at the Start Code Detector which generates a PICTURE\_END control token. The PICTURE\_END control token is passed unaltered through the start-up control circuit to the DRAM interface. Here it is used to flush out the write swing buffers in the DRAM interface. Recall, that the contents of a swing buffer are only written to RAM when the buffer is full. However, a picture may end at a point where the buffer is not full, therefore, causing the picture data to become stuck. The PICTURE\_END token forces the data out of the swing buffer.

Since the present invention is a multi-standard machine, the machine operates differently for each compression standard. More particularly, the machine is fully described as operating pursuant to machine-dependent action cycles. For each compression standard, a certain number of the total available action cycles can be selected by a combination of control tokens and/or output signals from the MPU or they can be selected by the design of the control tokens themselves. In this regard, the present invention is organized so as to delay the information from going into subsequent blocks until all of the information has been collected in an upstream block. The system waits until the data has been prepared for passing to the next stage. In this way, the PICTURE\_END signal is applied to the coded data buffer, and the control portion of the PICTURE\_END signal causes the contents of the data buffers to be read and applied to the Huffman decoder and video demultiplexor circuit.

Another advantage of the PICTURE\_END control token is to identify, for the use by the Huffman decoder

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art machine would stop itself because of an error condition. As previously described, the coded data buffer counts macroblocks as they come into its storage area. In addition, the Huffman Decoder and Video Demultiplexor  
5 generally know the amount of information expected for decoding each picture, i.e., the state machine portion of the Huffman decode and Video Demultiplexor know the number of blocks that it will process during each picture recovery cycle. When the correct number of blocks do not arrive  
10 from the coded data buffer, typically an error recovery routine would result. However, with the PICTURE\_END control token having reconfigured the Huffman Decoder and Video Demultiplexor, it can continue to function because the reconfiguration tells the Huffman Decoder and Video  
15 Demultiplexor that it is, indeed, handling the proper amount of information.

Referring again to Figure 10, the Token Decoder portion of the Buffer Manager detects the PICTURE\_END control token generated by the Start Code Detector. Under normal operations, the buffer registers fill up and are emptied, as previously described with reference to the normal operation of the swing buffers. Again, a swing buffer which is partially full of data will not empty until it is totally filled and/or it knows that it is time to empty. The PICTURE\_END control token is decoded in the Token Decoder portion of the Buffer Manager, and it forces the partially full swing buffer to empty itself into the coded data buffer. This is ultimately passed to the Huffman Decoder and Video Demultiplexor either directly or through the DRAM interface.

## 19. FLUSHING OPERATION

Another advantage of the PICTURE\_END control token is its function in connection with a FLUSH token. The FLUSH

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The FLUSH token, in accordance with the present invention, is used to pass through the entire pipeline processor and to ensure that the buffers are emptied and that other circuits are reconfigured to await the arrival

of new data. More specifically, the present invention comprises a combination of a PICTURE\_END token, a padding word and a FLUSH token indicating to the serial pipeline processor that the picture processing for the current picture form is completed. Thereafter, the various state machines need reconfiguring to await the arrival of new data for new handling. Note also that the FLUSH Token acts as a special reset for the system. The FLUSH token resets each stage as it passes through, but allows subsequent stages to continue processing. This prevents a loss of data. In other words, the FLUSH token is a variable reset, as opposed to, an absolute reset.

#### 21. STOP-AFTER PICTURE

The STOP\_AFTER\_PICTURE function is employed to shut down the processing of the serial pipeline decompressing circuit at a logical point in its operation. At this point, a PICTURE\_END token is generated indicating that data is finished coming in from the data input line, and the padding operation has been completed. The padding function fills partially empty DATA tokens. A FLUSH token is then generated which passes through the serial pipeline system and pushes all the information out of the registers and forces the registers back into their neutral stand-by condition. The STOP\_AFTER\_PICTURE event is then generated and no more input is accepted until either the user or the system clears this state. In other words, while a PICTURE\_END token signals the end of a picture, the STOP\_AFTER\_PICTURE operation signals the end of all current processing.

#### 22. MULTI-STANDARD - SEARCH MODE

Another feature of the present invention is the use of a SEARCH\_MODE control token which is used to reconfigure

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group\_start standard image. When such an image is identified, the Start Code Detector generates a GROUP\_START token and the search mode is reset automatically.

It is important to note that a single circuit, the Huffman Decoder and Video Demultiplex circuit, is operating with a combination of input signals including the standard-independent set-up signals, as well as, the CODING\_STANDARD signals. The CODING\_STANDARD signals are conveying information directly from the incoming bit stream as required by the Huffman Decoder and Video Demultiplex circuit. Nevertheless, while the functioning of the Huffman Decoder and Video Demultiplex circuit is under the operation of the standard independent sequence of signals.

This mode of operation has been selected because it is the most efficient and could have been designed wherein special control tokens are employed for conveying the standard-dependent input to the Huffman Decoder and Video Demultiplexer instead of conveying the actual signals themselves.

## 23. INVERSE MODELLER

Inverse modeling is a feature of all three standards, and is the same for all three standards. In general, DATA tokens in the token buffer contain information about the values of the quantized coefficients, and about the number of zeros between the coefficients that are represented (a form of run length coding). The Inverse Modeller of the present invention has been adapted for use with tokens and simply expands the information about runs of zeros so that each DATA Token contains the requisite 64 values. Thereafter, the values in the DATA Tokens are quantized coefficients which can be used by the Inverse Quantizer.

## 24. INVERSE QUANTIZER

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The Inverse Quantizer of the present invention is a required element in the decoding sequence, but has been implemented in such away to allow the entire IC set to handle multi-standard data. In addition, the Inverse

5 Quantizer has been adapted for use with tokens. The Inverse Quantizer lies between the Inverse modeller and inverse DCT (IDCT).

For example, in the present invention, an adder in the Inverse Quantizer is used to add a constant to the pel

10 decode number before the data moves on to the IDCT.

The IDCT uses the pel decode number, which will vary according to each standard used to encode the information. In order for the information to be properly decoded, a value of 1024 is added to the decode number by the Inverse

15 Quantizer before the data continues on to the IDCT.

Using adders, already present in the Inverse Quantizer, to standardize the data prior to it reaching the IDCT, eliminates the need for additional circuitry or software in the IC, for handling data compressed by the

20 various standards. Other operations allowing for multi-standard operation are performed during a "post quantization function" and are discussed below.

The control tokens accompanying the data are decoded and the various standardization routines that need to be

25 performed by the Inverse Quantizer are identified in detail below. These "post quantization" functions are all implemented to avoid duplicate circuitry and to allow the IC to handle multi-standard encoded data.

## 25. HUFFMAN DECODER AND PARSER

30 Referring again to Figures 11 and 27, the Spatial Decoder includes a Huffman Decoder for decoding the data that the various compression standards have Huffman-encoded. While each of the standards, JPEG, MPEG and

H.261, require certain data to be Huffman encoded, the Huffman decoding required by each standard differs in some significant ways. In the Spatial Decoder of the present invention, rather than design and fabricate three separate Huffman decoders, one for each standard, the present invention saves valuable die space by identifying common aspects of each Huffman Decoder, and fabricating these common aspects only once. Moreover, a clever multi-part algorithm is used that makes common more aspects of each Huffman Decoder common to the other standards as well than would otherwise be the case.

In brief, the Huffman Decoder 321 works in conjunction with the other units shown in Figure 27. These other units are the Parser State Machine 322, the inshifter 323, the Index to Data unit 324, the ALU 325, and the Token Formatter 326. As described previously, connection between these blocks is governed by a two wire interface. A more detailed description of how these units function is subsequently described herein in greater detail, the focus here is on particular aspects of the Huffman Decoder, in accordance with the present invention, that support multi-standard operation.

The Parser State Machine of the present invention, is a programmable state machine that acts to coordinate the operation of the other blocks of the Video Parser. In response to data, the Parser State Machine controls the other system blocks by generating a control word which is passed to the other blocks, side by side with the data, upon which this control word acts. Passing the control word alongside the associated data is not only useful, it is essential, since these blocks are connected via a two-wire interface. In this way, both data and control arrive at the same time. The passing of the control word is indicated in Figure 27 by a control line 327 that runs

beneath the data line 328 that connects the blocks. Among other things, this code word identifies the particular standard that is being decoded.

The Huffman decoder 321 also performs certain control functions. In particular, the Huffman Decoder 321 contains a state machine that can control certain functions of the Index to Data 324 and ALU 325. Control of these units by the Huffman Decoder is necessary for proper decoding of block-level information. Having the Parser State Machine 322 make these decisions would take too much time.

An important aspect of the Huffman Decoder of the present invention, is the ability to invert the coded data bits as they are read into the Huffman Decoder. This is needed to decode H.261 style Huffman codes, since the particular type of Huffman code used by H.261 (and substantially by MPEG) has the opposite polarity then the codes used by JPEG. The use of an inverter, thereby, allows substantially the same table to be used by the Huffman Decoder for all three standards. Other aspects of how the Huffman Decoder implements all three standards are discussed in further detail in the "More Detailed Description of the Invention" section.

The Index to Data unit 324 performs the second part of the multi-part algorithm. This unit contains a look up table that provides the actual Huffman decoded data. Entries in the table are organized based on the index numbers generated by the Huffman Decoder.

The ALU 325 implements the remaining parts of the multi-part algorithm. In particular, the ALU handles sign-extension. The ALU also includes a register file which holds vector predictions and DC predictions, the use of which is described in the sections related to prediction filters. The ALU, further, includes counters that count through the structure of the picture being decoded by the

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Spatial Decoder. In particular, the dimensions of the picture are programmed into registers associated with the counters, which facilitates detection of "start of picture," and start of macroblock codes.

5        In accordance with the present invention, the Token Formatter 326 (TF) assembles decoded data into DATA tokens that are then passed onto the remaining stages or blocks in the Spatial Decoder.

10        In the present invention, the in shifter 323 receives data from a FIFO that buffers the data passing through the Start Code Detector. The data received by the inshifter is generally of two types: DATA tokens, and start codes which the Start Code Detector has replaced with their respective tokens, as discussed further in the token section. Note  
15        that most of the data will be DATA tokens that require decoding.

20        The in shifter 323 serially passes data to the Huffman Decoder 321. On the other hand, it passes control tokens in parallel. In the Huffman decoder, the Huffman encoded data is decoded in accordance with the first part of the multi-part algorithm. In particular, the particular Huffman code is identified, and then replaced with an index number.

25        The Huffman Decoder 321 also identifies certain data that requires special handling by the other blocks shown in Figure 27. This data includes end of block and escape. In the present invention, time is saved by detecting these in the Huffman Decoder 321, rather than in the Index to Data unit 324.

30        This index number is then passed to the Index to Data unit 324. In essence, the Index to Data unit is a look-up table. In accordance with one aspect of the algorithm, the look-up table is little more than the Huffman code table specified by JPEG. Generally, it is in the condensed data

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format that JPEG specifies for transferring an alternate JPEG table.

From the Index to Data unit 324, the decoded index number or other data is passed, together with the  
 5 accompanying control word, to the ALU 325, which performs the operations previously described.

From the ALU 325, the data and control word is passed to the Token Formatter 326 (TF). In the Token Formatter, the data is combined as needed with the control word to  
 10 form tokens. The tokens are then conveyed to the next stages of the Spatial Decoder. Note that at this point, there are as many tokens as will be used by the system.

## 26. INVERSE DISCRETE COSINE TRANSFORM

The Inverse Discrete Cosine Transform (IDCT), in  
 15 accordance with the present invention, decompresses data related to the frequency of the DC component of the picture. When a particular picture is being compressed, the frequency of the light in the picture is quantized, reducing the overall amount of information needed to be  
 20 stored. The IDCT takes this quantized data and decompresses it back into frequency information.

The IDCT operates on a portion of the picture which is 8x8 pixels in size. The math which performed on this data is largely governed by the particular standard used to  
 25 encode the data. However, in the present invention, significant use is made of common mathematical functions between the standards to avoid unnecessary duplication of circuitry.

Using a particular scaling order, the symmetry between  
 30 the upper and lower portions of the algorithms is increased, thus common mathematical functions can be reused which eliminates the need for additional circuitry.

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## 27. BUFFER MANAGER

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The foregoing description is believed to adequately describe the overall concepts, system implementation and operation of the various aspects of the invention in sufficient detail to enable one of ordinary skill in the art to make and practice the invention with all of its attendant features, objects and advantages. However, in order to facilitate a further, more detailed in depth understanding of the invention, and additional details in connection with even more specific, commercial implementation of various embodiments of the invention, the following further description and explanation is preferred.

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This is a more detailed description for a multi-standard video decoder chip-set. It is divided into three main sections: A, B and C.

Again, for purposes of organization, clarity and  
 5 convenience of explanation, this additional disclosure is set forth in the following sections.

·Description of features common to chips in the chip-set:

- Tokens
- 10 ·Two wire interfaces
- DRAM interface
- Microprocessor interface
- Clocks
- Description of the Spatial Decoder chip
- 15 ·Description of the Temporal Decoder chip

## SECTION A.1

The first description section covers the majority of the electrical design issues associated with using the chip-set.

### 20 A.1.1 Typographic conventions

A small set of typographic conventions is used to emphasize some classes of information:

#### **NAMES\_OF\_TOKENS**

- wire\_name active high signal
- 25 wire\_name active low signal
- register\_name

## SECTION A.2 Video Decoder Family

- 30 MHz operation
- Decodes MPEG, JPEG & H.261
- Coded data rates to 25 Mb/s
- 5 · Video data rates to 21 MB/s
- MPEG resolutions up to 704 x 480, 30 Hz, 4:2:0
- Flexible chroma sampling formats
- Full JPEG baseline decoding
- Glue-less page mode DRAM interface
- 10 · 208 pin PQFP package
- Independent coded data and decoder clocks
- Re-orders MPEG picture sequence

The Video decoder family provides a low chip count solution for implementing high resolution digital video decoders. The chip-set is currently configurable to support three different video and picture coding systems: JPEG, MPEG and H.261.

Full JPEG baseline picture decoding is supported. 720 x 480, 30 Hz, 4:2:2 JPEG encoded video can be decoded in real-time.

CIF (Common Interchange Format) and QCIF H.261 video can be decoded. Full feature MPEG video with formats up to 740 x 480, 30 Hz, 4:2:0 can be decoded.

Note: The above values are merely illustrative, by way of example and not necessarily by way of limitation, of one embodiment of the present invention. Accordingly, it will be appreciated that other values and/or ranges may be used.

### A.2.1 System configurations

#### A.2.1.1 Output formatting

In each of the examples given below, some form of output formatter will be required to take the data presented at the output of the Spatial Decoder or Temporal Decoder and

re-format it for a computer or display system. The details of this formatting will vary between applications. In a simple case, all that is required is an address generator to take the block formatted data output by the decoder chip and write it into memory in a raster order.

The Image Formatter is a single chip VLSI device providing a wide range of output formatting functions.

#### **A.2.1.2 JPEG still picture decoding**

A single Spatial Decoder, with no-off-chip DRAM, can rapidly decode baseline JPEG images. The Spatial Decoder will support all features of baseline JPEG. However, the image size that can be decoded may be limited by the size of the output buffer provided by the user. The characteristics of the output formatter may limit the chroma sampling formats and color spaces that can be supported.

#### **A.2.1.3 JPEG video decoding**

Adding off-chip DRAMs to the Spatial Decoder allows it to decode JPEG encoded video pictures in real-time. The size and speed of the required buffers will depend on the video and coded data rates. The Temporal Decoder is not required to decode JPEG encoded video. However, if a Temporal Decoder is present in a multi-standard decoder chip-set, it will merely pass the data through the Temporal Decoder without alteration or modification when the system is configured for JPEG operation.

#### **A.2.1.4 H.261 decoding**

The Spatial Decoder and the Temporal Decoder are both required to implement an H.261 video decoder. The DRAM interfaces on both devices are configurable to allow the quantity of DRAM required for proper operation to be reduced when working with small picture formats and at low coded data rates. Typically, a single 4Mb (e.g. 512k x 8) DRAM will be required by each of the Spatial Decoder and

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the Temporal Decoder.

#### A.2.1.5 MPEG decoding

The configuration required for MPEG operation is the same as for H.261. However, as will be appreciated by one  
5 of ordinary skill in the art, larger DRAM buffers may be required to support the larger picture formats possible with MPEG.

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### A.3.1 Token format

In accordance with the present invention, tokens provide an extensible format for communicating information through the decoder chip-set. While in the present invention, each word of a Token is a minimum of 8 bits wide, one of ordinary skill in the art will appreciate that tokens can be of any width. Furthermore, a single Token can be spread over one or more words; this is accomplished using an extension bit in each word. The formats for the tokens are summarized in Table A.3.1.

The extension bit indicates whether a Token continues into another word. It is set to 1 in all words of a Token except the last one. If the first word of a Token has an extension bit of 0, this indicates that the Token is only one word long.

Each Token is identified by an Address Field that starts in bit 7 of the first word of the Token. The Address Field is of variable length and can potentially extend over multiple words (in the current chips no address is more than 8 bits long, however, one of ordinary skill in the art will again appreciate that addresses can be of any length).

Some interfaces transfer more than 8 bits of data. For example, the output of the Spatial Decoder is 9 bits wide (10 bits including the extension bit). The only Token that takes advantage of these extra bits is the DATA Token. The DATA Token can have as many bits as are necessary for carrying out processing at a particular place in the system. All other Tokens ignore the extra bits.

### A.3.2 The DATA Token

The DATA Token carries data from one processing stage to the next. Consequently, the characteristics of this Token change as it passes through the decoder. Furthermore, the meaning of the data carried by the DATA Token varies depending on where the DATA Token is within the system, i.e., the data is position dependent. In this regard, the data may be either frequency domain or Pel domain data depending on where the DATA Token is within the Spatial Decoder. For example, at the input of the Spatial Decoder, DATA Tokens carry bit serial coded video data packed into 8 bit words. At this point, there is no limit to the length of each Token. In contrast, however, at the output of the Spatial Decoder each DATA Token carries exactly 64 words and each word is 9 bits wide.

#### A.3.3 Using Token formatted data

In some applications, it may be necessary for the circuitry that connect directly to the input or output of the Decoder or chip set. In most cases it will be sufficient to collect DATA Tokens and to detect a few Tokens that provide synchronization information (such as PICTURE\_START). In this regard, see subsequent sections A.16, "Connecting to the output of Spatial Decoder", and A.19, "Connecting to the output of the Temporal Decoder".

As discussed above, it is sufficient to observe activity on the extension bit to identify when each new Token starts. Again, the extension bit signals the last word of the current token. In addition, the Address field can be tested to identify the Token. Unwanted or unrecognized Tokens can be consumed (and discarded) without knowledge of their content. However, a recognized token causes an appropriate action to occur.

Furthermore, the data input to the Spatial Decoder can either be supplied as bytes of coded data, or in DATA Tokens (see Section A.10, "Coded data input"). Supplying Tokens via the coded data port or via the microprocessor  
5 interface allows many of the features of the decoder chip set to be configured from the data stream. This provides an alternative to doing the configuration via the micro processor interface.

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7	6	5	4	3	2	1	0	Token Name	Reference
0	0	1						QUANT_SCALE	
0	1	0						PREDICTION_MODE	
0	1	1						(reserved)	
1	0	0						MVD_FORWARDS	
1	0	1						MVD_BACKWARDS	
0	0	0	0	1				QUANT_TABLE	
0	0	0	0	0	1			DATA	
1	1	0	0	0	0			COMPONENT_NAME	
1	1	0	0	0	1			DEFINE_SAMPLING	
1	1	0	0	1	0			JPEG_TABLE_SELECT	
1	1	0	0	1	1			MPEG_TABLE_SELECT	
1	1	0	1	0	0			TEMPORAL_REFERENCE	
1	1	0	1	0	1			MPEG_DCH_TABLE	
1	1	0	1	1	0			(reserved)	
1	1	0	1	1	1			(reserved)	
1	1	1	0	0	0	0		(reserved) SAVE_STATE	
1	1	1	0	0	0	1		(reserved) RESTORE_STATE	
1	1	1	0	0	1	0		TIME_CODE	
1	1	1	0	0	1	1		(reserved)	
0	0	0	0	0	0	0	0	NULL	
0	0	0	0	0	0	0	1	(reserved)	
0	0	0	0	0	0	1	0	(reserved)	
0	0	0	0	0	0	1	1	(reserved)	
0	0	0	1	0	0	0	0	SEQUENCE_START	
0	0	0	1	0	0	0	1	GROUP_START	
0	0	0	1	0	0	1	0	PICTURE_START	
0	0	0	1	0	0	1	1	SLICE_START	
0	0	0	1	0	1	0	0	SEQUENCE_END	
0	0	0	1	0	1	0	1	CODING_STANDARD	
0	0	0	1	0	1	1	0	PICTURE_END	
0	0	0	1	0	1	1	1	FLUSH	
0	0	0	1	1	0	0	0	FIELD_INFO	

Table A.3.1 Summary of Tokens

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7	6	5	4	3	2	1	0	Token Name	Reference
0	0	0	1	1	0	0	1	MAX_COMP_ID	
0	0	0	1	1	0	1	0	EXTENSION_DATA	
0	0	0	1	1	0	1	1	USER_DATA	
0	0	0	1	1	1	0	0	DHT_MARKER	
0	0	0	1	1	1	0	1	DQT_MARKER	
0	0	0	1	1	1	1	0	(reserved) DNL_MARKER	
0	0	0	1	1	1	1	1	(reserved) DRI_MARKER	
1	1	1	0	1	0	0	0	(reserved)	
1	1	1	0	1	0	0	1	(reserved)	
1	1	1	0	1	0	1	0	(reserved)	
1	1	1	0	1	0	1	1	(reserved)	
1	1	1	0	1	1	0	0	BIT_RATE	
1	1	1	0	1	1	0	1	VBV_BUFFER_SIZE	
1	1	1	0	1	1	1	0	VBV_DELAY	
1	1	1	0	1	1	1	1	PICTURE_TYPE	
1	1	1	1	0	0	0	0	PICTURE_RATE	
1	1	1	1	0	0	0	1	PEL_ASPECT	
1	1	1	1	0	0	1	0	HORIZONTAL_SIZE	
1	1	1	1	0	0	1	1	VERTICAL_SIZE	
1	1	1	1	0	1	0	0	BROKEN_CLOSED	
1	1	1	1	0	1	0	1	CONSTRAINED	
1	1	1	1	0	1	1	0	(reserved) SPECTRAL_LIMIT	
1	1	1	1	0	1	1	1	DEFINE_MAX_SAMPLING	
1	1	1	1	1	0	0	0	(reserved)	
1	1	1	1	1	0	0	1	(reserved)	
1	1	1	1	1	0	1	0	(reserved)	
1	1	1	1	1	0	1	1	(reserved)	
1	1	1	1	1	1	0	0	HORIZONTAL_MBS	
1	1	1	1	1	1	0	1	VERTICAL_MBS	
1	1	1	1	1	1	1	0	(reserved)	
1	1	1	1	1	1	1	1	(reserved)	

Table A.3.1 Summary of Tokens (contd)

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#### A.3.4 Description of Tokens

This section documents the Tokens which are implemented in the Spatial Decoder and the Temporal Decoder chips in accordance with the present invention; see Table A.3.2.

5 Note:

."r" signifies bits that are currently reserved and carry the value 0

.unless indicated all integers are unsigned

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E	7	6	5	4	3	2	1	0	Description
1	1	1	1	0	1	1	0	0	BIT_RATE test info only
1	r	r	r	r	r	r	b	b	Carries the MPEG bit rate parameter R. Generated by the Huffman decoder when decoding an MPEG bitstream.  b - an 18 bit integer as defined by MPEG
1	b	b	b	b	b	b	b	b	
0	b	b	b	b	b	b	b	b	
1	1	1	1	1	0	1	0	0	BROKEN_CLOSED
0	r	r	r	r	r	r	c	b	Carries two MPEG flags bits:  c - closed_gop  b - broken_link
1	0	0	0	1	0	1	0	1	CODING_STANDARD
0	s	s	s	s	s	s	s	s	s - an 8 bit integer indicating the current coding standard. The values currently assigned are:  0 - H.261  1 - JPEG  2 - MPEG
1	1	1	0	0	0	0	c	c	COMPONENT_NAME
0	n	n	n	n	n	n	n	n	Communicates the relationship between a component ID and the component name. See also ...  c - 2 bit component ID  n - 8 bit component "name"
1	1	1	1	1	0	1	0	1	CONSTRAINED
0	r	r	r	r	r	r	r	c	c - carries the constrained_parameters_flag decoded from an MPEG bitstream.

Table A.3.2 Tokens implemented in the Spatial Decoder and Temporal Decoder (Sheet 1 of 9)

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E	7	6	5	4	3	2	1	0	Description
1	0	0	0	0	0	1	c	c	<b>DATA</b>
1	d	d	d	d	d	d	d	d	Carries data through the decoder chip-set.
0	d	d	d	d	d	d	d	d	c - a 2 bit integer component ID (see A.3.5.1) This field is not defined for Tokens that carry coded data (rather than pixel information).
1	1	1	1	1	0	1	1	1	<b>DEFINE_MAX_SAMPLING</b>
1	r	r	r	r	r	r	h	h	Max. Horizontal and Vertical sampling numbers. These describe the maximum number of blocks horizontally/vertically in any component of a macroblock. See A.3.5.2
0	r	r	r	r	r	r	v	v	h - 2 bit horizontal sampling number. v - 2 bit vertical sampling number.
1	1	1	0	0	0	1	c	c	<b>DEFINE_SAMPLING</b>
1	r	r	r	r	r	r	h	h	Horizontal and Vertical sampling numbers for a particular colour component. See A.3.5.2
0	r	r	r	r	r	r	v	v	c - 2 bit component ID. h - 2 bit horizontal sampling number. v - 2 bit vertical sampling number.
0	0	0	0	1	1	1	0	0	<b>DHT_MARKER</b>
									This Token informs the Video Demux that the DATA Token that follows contains the specification of a Huffman table described using the JPEG "define Huffman table segment" syntax. This Token is only valid when the coding standard is configured as JPEG.  This Token is generated by the start code detector during JPEG decoding when a DHT marker has been encountered in the data stream.

Table A.3.2 Tokens implemented in the Spatial Decoder and Temporal Decoder (Sheet 2 of 9)

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E	7	6	5	4	3	2	1	0	Description
0	0	0	0	1	1	1	1	0	<b>DNL_MARKER</b>  This Token informs the Video Demux that the DATA Token that follows contains the JPEG parameter NL which specifies the number of lines in a frame.  This Token is generated by the start code detector during JPEG decoding when a DNL marker has been encountered in the data stream.
0	0	0	0	1	1	1	0	1	<b>DQT_MARKER</b>  This Token informs the Video Demux that the DATA Token that follows contains the specification of a quantisation table described using the JPEG "define quantisation table segment" syntax. This Token is only valid when the coding standard is configured as JPEG. The Video Demux generates a QUANT_TABLE Token containing the new quantisation table information.  This Token is generated by the start code detector during JPEG decoding when a DQT marker has been encountered in the data stream.
0	0	0	0	1	1	1	1	1	<b>DRI_MARKER</b>  This Token informs the Video Demux that the DATA Token that follows contains the JPEG parameter Ri which specifies the number of minimum coding units between restart markers.  This Token is generated by the start code detector during JPEG decoding when a DRI marker has been encountered in the data stream.

Table A.3.2 Tokens implemented in the Spatial Decoder and Temporal Decoder (Sheet 3 of 9)

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E	7	6	5	4	3	2	1	0	Description
1	0	0	0	1	1	0	1	0	<b>EXTENSION_DATA JPEG</b>
0	v	v	v	v	v	v	v	v	<p>This Token informs the Video Demux that the DATA Token that follows contains extension data. See A.11.3, "Conversion of start codes to Tokens", and A.14.6, "Receiving User and Extension data".</p> <p>During JPEG operation the 8 bit field 'v' carries the JPEG marker value. This allows the class of extension data to be identified.</p>
0	0	0	0	1	1	0	1	0	<b>EXTENSION_DATA MPEG</b>
									<p>This Token informs the Video Demux that the DATA Token that follows contains extension data. See A.11.3, "Conversion of start codes to Tokens", and A.14.6, "Receiving User and Extension data".</p>
1	0	0	0	1	1	0	0	0	<b>FIELD_INFO</b>
0	r	r	r	t	p	f	f	f	<p>Carries information about the picture following to aid its display.</p> <p>This function is not signalled by any existing coding standard.</p> <p>t - if the picture is an interlaced frame this bit indicates if the upper field is first (t=0) or second.</p> <p>p - if pictures are fields this indicates if the next picture is upper (p=0) or lower in the frame.</p> <p>f - a 3 bit number indicating position of the field in the 8 field PAL sequence.</p>
0	0	0	0	1	0	1	1	1	<b>FLUSH</b>
									Used to indicate the end of the current coded data and to push the end of the data stream through the decoder.
0	0	0	0	1	0	0	0	1	<b>GROUP_START</b>
									<p>Generated when the group of pictures start code is found when decoding MPEG or the frame marker is found when decoding JPEG.</p>

Table A.3.2 Tokens implemented in the Spatial Decoder and Temporal Decoder (Sheet 4 of

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E	7	6	5	4	3	2	1	0	Description
1	1	1	1	1	1	1	0	0	<b>HORIZONTAL_MBS</b>  h - a 13 bit number integer indicating the horizontal width of the picture in macroblocks.
1	r	r	r	r	h	h	h	h	
0	h	h	h	h	h	h	h	h	
1	1	1	1	1	0	0	1	0	<b>HORIZONTAL_SIZE</b>  h - 16 bit number integer indicating the horizontal width of the picture in pixels. This can be any integer value.
1	h	h	h	h	h	h	h	h	
0	h	h	h	h	h	h	h	h	
1	1	1	0	0	1	0	c	c	<b>JPEG_TABLE_SELECT</b>  Informs the inverse quantiser which quantisation table to use on the specified colour component.  c - 2 bit component ID (see A.3.5.1)  t - 2 bit integer table number.
0	r	r	r	r	r	r	t	t	
1	0	0	0	1	1	0	0	1	<b>MAX_COMP_ID</b>  m - 2 bit integer indicating the maximum value of component ID (see A.3.5.1) that will be used in the next picture.
0	r	r	r	r	r	r	m	m	
0	1	1	0	1	0	1	c	c	<b>MPEG_DCH_TABLE</b>  Configures which DC coefficient Huffman table should be used for colour component cc.  c - 2 bit component ID (see A.3.5.1)  t - 2 bit integer table number.
0	r	r	r	r	r	r	t	t	
0	1	1	0	0	1	1	d	n	<b>MPEG_TABLE_SELECT</b>  Informs the inverse quantiser whether to use the default or user defined quantisation table for intra or non-intra information.  n - 0 indicates intra information, 1 non-intra.  d - 0 indicates default table, 1 user defined.

Table A.3.2 Tokens implemented in the Spatial Decoder and Temporal Decoder (Sheet 5 of 9)

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Table A.3.2 Tokens implemented in the Spatial Decoder and Temporal Decoder (Sheet 6 of 9)

E	7	6	5	4	3	2	1	0	Description
1	1	1	1	0	1	1	1	1	PICTURE_TYPE MPEG
0	r	r	r	r	r	r	p	p	<p>p - a 2 bit integer indicating the picture coding type of the picture that follows:</p> <p>0 - Intra</p> <p>1 - Predicted</p> <p>2 - Bidirectionally Predicted</p> <p>3 - DC Intra</p>
1	1	1	1	0	1	1	1	1	PICTURE_TYPE H.261
1	r	r	r	r	r	r	0	1	Indicates various H.261 options are on (1) or off (0). These options are always off for MPEG and JPEG:
0	r	r	s	d	f	q	1	1	<p>s - Split Screen Indicator</p> <p>d - Document Camera</p> <p>f - Freeze Picture Release</p> <p>Source picture format:</p> <p>q = 0 - QCIF</p> <p>q = 1 - CIF</p>
0	0	1	0	h	y	x	b	1	PREDICTION_MODE
									<p>A set of flag bits that indicate the prediction mode for the macroblocks that follow:</p> <p>f - forward prediction</p> <p>b - backward prediction</p> <p>x - reset forward vector predictor</p> <p>y - reset backward vector predictor</p> <p>h - enable H.261 loop filter</p>
0	0	0	1	s	s	s	s	s	QUANT_SCALE
									<p>Informs the inverse quantiser of a new scale factor</p> <p>s - 5 bit integer in range 1 ... 31. The value 0 is reserved.</p>

Table A.3.2 Tokens implemented in the Spatial Decoder and Temporal Decoder (Sheet 7 of

E	7	6	5	4	3	2	1	0	Description
1	0	0	0	0	1	r	t	t	<b>QUANT_TABLE</b>  Loads the specified inverse quantiser table with 64 8 bit unsigned integers. The values are in zig-zag order.  t - 2 bit integer specifying the inverse quantiser table to be loaded
1	q	q	q	q	q	q	q	q	
0	q	q	q	q	q	q	q	q	
0	0	0	0	1	0	1	0	0	<b>SEQUENCE_END</b>  The MPEG sequence_end_code and the JPEG EOI marker cause this Token to be generated.
0	0	0	0	1	0	0	0	0	<b>SEQUENCE_START</b>  Generated by the MPEG sequence_start start code.
1	0	0	0	1	0	0	1	1	<b>SLICE_START</b>  Corresponds to the MPEG slice_start, the H.261 GOB and the JPEG resync interval. The interpretation of 8 bit integer "s" differs between coding standards:  MPEG - Slice Vertical Position - 1.  H.261 - Group of Blocks Number - 1.  JPEG - resynchronisation interval identification (4 LSBs only).
0	s	s	s	s	s	s	s	s	
0	s	s	s	s	s	s	s	s	
1	1	1	0	1	0	0	t	t	<b>TEMPORAL_REFERENCE</b>  t - carries the temporal reference. For MPEG this is a 10 bit integer. For H.261 only the 5 LSBs are used, the MSBs will always be zero.
0	t	t	t	t	t	t	t	t	
1	1	1	1	0	0	1	0	d	<b>TIME_CODE</b>  The MPEG time_code:  d - Drop frame flag  h - 5 bit integer specifying hours  m - 6 bit integer specifying minutes  s - 6 bit integer specifying seconds  p - 6 bit integer specifying pictures
1	r	r	r	h	h	h	h	h	
1	r	r	m	m	m	m	m	m	
1	r	r	s	s	s	s	s	s	
0	r	r	p	p	p	p	p	p	
0	r	r	p	p	p	p	p	p	

Table A.3.2 Tokens implemented in the Spatial Decoder and Temporal Decoder (Sheet 8 of

Table A.3.2 Tokens implemented in the Spatial Decoder and Temporal Decoder (Sheet 9 of 9)

Table A.3.2 Tokens implemented in the Spatial Decoder and Temporal Decoder (Sheet 9 of 9)

#### A.3.5.1 Component Identification number

5 This 2 bit field is typically located as part of the Header  
in the DATA Token. With MPEG and H.261 the relationship is  
set forth in Table A.3.3.

Component ID	MPEG or H.261 colour component
0	Luminance (Y)
1	Blue difference signal (Cb / U)
2	Red difference signal (Cr / V)
3	Never used

**Table A.3.3 Component ID for MPEG and H.261**

With JPEG the situation is more complex as JPEG does not limit the color components that can be used. The decoder chips permit up to 4 different color components in each scan. The IDs are allocated sequentially as the  
 5 specification of color components arrive at the decoder.

#### A.3.5.2 Horizontal and Vertical sampling numbers

For each of the 4 color components, there is a specification for the number of blocks arranged horizontally and vertically in a macroblock. This  
 10 specification comprises a two bit integer which is one less than the number of blocks.

For example, in MPEG (or H.261) with 4:2:0 chroma sampling (Figure 36) and component IDs allocated as per Table A.3.4.

Component ID	Horizontal sampling number	Width in blocks	Vertical sampling number	Height in blocks
0	1	2	1	2
1	0	1	0	1
2	0	1	0	1
3	Not used	Not used	Not used	Not used

Table A.3.4 Sampling numbers for 4:2:0/MPEG

With JPEG and 4:2:2 chroma sampling (allocation of component to component ID will vary between applications. See A.3.5.1. Note: JPEG requires a 2:1:1 structure for its macroblocks when processing 4:2:2 data. See Table A.3.5.

Component ID	Horizontal sampling number	Width in blocks	Vertical sampling number	Height in blocks
Y	1	2	0	1
U	0	1	0	1
V	0	1	0	1

**Table A.3.5 Sampling numbers for 4:2:2 JPEG**

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### A.3.6 Special Token formats

In accordance with the present invention, tokens such as the DATA Token and the QUANT\_TABLE Token are used in their "extended form" within the decoder chip-set. In the extended form the Token includes some data. In the case of DATA Tokens, they can contain coded data or pixel data. In the case of QUANT\_TABLE tokens, they contain quantizer table information.

Furthermore, "non-extended form" of these Tokens is defined in the present invention as "empty". This Token format provides a place in the Token stream that can be subsequently filled by an extended version of the same Token. This format is mainly applicable to encoders and, therefore, it is not documented further here.

Token Name	MPEG	JPEG	H261
BIT_RATE	✓		
BROKEN_CLOSED	✓		
CODING_STANDARD	✓	✓	✓
COMPONENT_NAME		✓	
CONSTRAINED	✓		
DATA	✓	✓	✓
DEFINE_MAX_SAMPLING	✓	✓	✓
DEFINE_SAMPLING	✓	✓	✓
DHT_MARKER		✓	
DNL_MARKER		✓	
DQT_MARKER		✓	
DRI_MARKER		✓	

Table A.3.6 tokens for different standards



Token Name	MPEG	JPEG	H.261
EXTENSION_DATA	/	/	
FIELD_INFO			
FLUSH	/	/	/
GROUP_START	/	/	
HORIZONTAL_MBS	/	/	/
HORIZONTAL_SIZE	/	/	/
JPEG_TABLE_SELECT		/	
MAX_COMP_ID	/	/	/
MPEG_DCH_TABLE	/		
MPEG_TABLE_SELECT	/		
MVD_BACKWARDS	/		
MVD_FORWARDS	/		/
NULL	/	/	/
PEL_ASPECT	/		
PICTURE_END	/	/	/
PICTURE_RATE	/		
PICTURE_START	/	/	/
PICTURE_TYPE	/	/	/
PREDICTION_MODE	/	/	/
QUANT_SCALE	/		/
QUANT_TABLE	/	/	
SEQUENCE_END	/	/	
SEQUENCE_START	/	/	/
SLICE_START	/	/	/
TEMPORAL_REFERENCE	/		/
TIME_CODE	/		
USER_DATA	/	/	
VBV_BUFFER_SIZE	/		
VBV_DELAY	/		
VERTICAL_MBS	/	/	/
VERTICAL_SIZE	/	/	/

Table A.3.6 Tokens for different standards (contd)

**A.3.7 Use of Tokens for different standards**

Each standard uses a different sub-set of the defined Tokens in accordance with the present invention; ss Table A.3.6.

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25       The width of the data word transferred by the two-wire  
interface varies depending upon the needs of the interface  
concerned (See Figure 35, "Tokens on interfaces wider than  
8 bits". For example, 12 bit coefficients are input to the  
Inverse Discrete Cosine Transform (IDCT), but only 9 bits  
30       are output.

Interface	Data Width (bits)
Coded data input to Spatial Decoder	8
Output port of Spatial Decoder	9
Input port of Temporal Decoder	9
Output port of Temporal Decoder	8
Input port of Image Formatter	8

**Table A.4.1 Two wire interface data width**

In addition to the data signals there are three other signals transmitted via the two-wire interface:

.valid  
 .accept  
 .extension

#### **A.4.3.1 The extension signal**

The extension signal corresponds to the Token extension bit previously described.

#### **A.4.4 Design considerations**

The two wire interface is intended for short range, point to point communication between chips.

The decoder chips should be placed adjacent to each other, so as to minimize the length of the PCB tracks between chips. Where possible, track lengths should be kept below 25 mm. The PCB track capacitance should be kept to a minimum.

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The clock distribution should be designed to minimize the clock slew between chips. If there is any clock slew, it should be arranged so that "receiving chips" see the clock before "sending chips".<sup>1</sup>

- 5 All chips communicating via two wire interfaces should operate from the same digital power supply.

#### A.4.5 Interface timing

Num.	Characteristic	30 MHz		Unit	Note <sup>a</sup> b
		Min.	Max.		
1	Input signal set-up time	5		ns	
2	Input signal hold time	0		ns	
3	Output signal drive time		23	ns	
4	Output signal hold time	2		ns	

**Table A.4.2 Two wire interface timing**

- 10 a. Figures in Table A.4.2 may vary in accordance with design variations
- b. Maximum signal loading is approximately 20 pF

15 <sup>1</sup> Note: Figure 38 shows the two-wire interface between the system de-mux chip and the coded data port of the Spatial Decoder operating from the main decoder clock. This is optional as this two wire interface can work from the coded data clock which can be asynchronous to the decoder clock. See Section A.10.5, "Coded data clock". Similarly the display interface of the Image Formatter can operate from a clock that is asynchronous to the main decoder clock.

#### A.4.6 Signal levels

The two-wire interface uses CMOS inputs and output.

$V_{IHmin}$  is approx. 70% of  $V_{DD}$  and  $V_{ILmax}$  is approx. 30% of  $V_{DD}$ .

The values shown in Table A.4.3 are those for  $V_{IH}$  and  $V_{IL}$  at

5 their respective worst case  $V_{DD}$ .  $V_{DD}=5.0\pm0.25V$ .

Symbol	Parameter	Min.	Max.	Units
$V_{IH}$	Input logic '1' voltage	3.68	$V_{DD} - 0.5$	V
$V_{IL}$	Input logic '0' voltage	$GND + 0.5$	1.43	V
$V_{OH}$	Output logic '1' voltage	$V_{DD} - 0.1$		V <sup>a</sup>
		$V_{DD} - 0.4$		V <sup>b</sup>
$V_{OL}$	Output logic '0' voltage		0.1	V <sup>c</sup>
			0.4	V <sup>d</sup>
$I_{IN}$	Input leakage current		$\pm 10$	$\mu A$

Table A.4.3 DC electrical characteristics

a.  $I_{OH} \leq 1mA$

b.  $I_{OH} \leq 4mA$

c.  $I_{OL} \leq 1mA$

d.  $I_{OL} \leq 4mA$

#### A.4.7 Control clock

In general, the clock controlling the transfers across the two wire interface is the chip's decoder\_clock. The exception is the coded data port input to the Spatial  
5 Decoder. This is controlled by coded\_clock. The clock signals are further described herein.

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## SECTION A.5 DRAM Interface

### A.5.1 The DRAM interface

A single high performance, configurable, DRAM interface is used on each of the video decoder chips. In general, the DRAM interface on each chip is substantially the same; however, the interfaces differ from one another in how they handle channel priorities. The interface is designed to directly drive the DRAM used by each of the decoder chips. Typically, no external logic, buffers or components will be necessary to connect the DRAM interface to the DRAMs in most systems.

### A.5.2 Interface signals

Signal Name	Input / Output	Description
DRAM_data[31:0]	I/O	The 32 bit wide DRAM data bus. Optionally this bus can be configured to be 16 or 8 bits wide. See section A.5.8
DRAM_addr[10:0]	O	The 22 bit wide DRAM interface address is time multiplexed over this 11 bit wide bus.
RAS	O	The DRAM Row Address Strobe signal
CAS[3:0]	O	The DRAM Column Address Strobe signal. One signal is provided per byte of the interface's data bus. All the CAS signals are driven simultaneously.
WE	O	The DRAM Write Enable signal
OE	O	The DRAM Output Enable signal
DRAM_enable	I	This input signal, when low, makes all the output signals on the interface go high impedance.  Note: on-chip data processing is not stopped when the DRAM interface is high impedance. So, errors will occur if the chip attempts to access DRAM while DRAM_enable is low.

Table A.5.1 DRAM interface signals

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In accordance with the present invention, the interface is configurable in two ways:

- .The detail timing of the interface can be configured to accommodate a variety of different DRAM types
- .The "width" of the DRAM interface can be configured to provide a cost/performance trade-off in different applications.

### A.5.3 Configuring the DRAM interface

Generally, there are three groups of registers associated with the DRAM interface: interface timing configuration registers, interface bus configuration registers and refresh configuration registers. The refresh configuration registers (registers in Table A.5.4) should be configured last.

#### A.5.3.1 Conditions after reset

After reset, the DRAM interface, in accordance with the present invention, starts operation with a set of default timing parameters (that correspond to the slowest mode of operation). Initially, the DRAM interface will continually execute refresh cycles (excluding all other transfers). This will continue until a value is written into refresh\_interval. The DRAM interface will then be able to perform other types of transfer between refresh cycles.

#### A.5.3.2 Bus configuration

Bus configuration (registers in Table A.5.3) should only be done when no data transfers are being attempted by the interface. The interface is placed in this condition immediately after reset, and before a value is written into refresh\_interval. The interface can be re-configured later, if required, only when no transfers are being attempted. See the Temporal Decoder chip\_access register (A.13.3.1) and the Spatial Decoder buffer\_manager\_access register (A.13.1.1).

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## A.5.5 Interface registers

Register name	Size/Dir	Reset State	Description
interface_timing_access	1 bit  rw	0	This function enable register allows access to the DRAM interface timing configuration registers. The configuration registers should not be modified while this register holds the value 0. Writing a one to this register requests access to modify the configuration registers. After a 0 has been written to this register the DRAM interface will start to use the new values in the timing configuration registers.
page_start_length	5 bit  rw	0	Specifies the length of the access start in ticks. The minimum value that can be used is 4 (meaning 4 ticks). 0 selects the maximum length of 32 ticks.
transfer_cycle_length	4 bit  rw	0	Specifies the length of the fast page read or write cycle in ticks. The minimum value that can be used is 4 (meaning 4 ticks). 0 selects the maximum length of 16 ticks.
refresh_cycle_length	4 bit  rw	0	Specifies the length of the refresh cycle in ticks. The minimum value that can be used is 4 (meaning 4 ticks). 0 selects the maximum length of 16 ticks.
RAS_falling	4 bit  rw	0	Specifies the number of ticks after the start of the access start that RAS falls. The minimum value that can be used is 4 (meaning 4 ticks). 0 selects the maximum length of 16 ticks.
CAS_falling	4 bit  rw	0	Specifies the number of ticks after the start of a read cycle, write cycle or access start that CAS falls. The minimum value that can be used is 1 (meaning 1 tick). 0 selects the maximum length of 16 ticks.

Table A.5.2 Interface timing configuration registers

00000000000000000000000000000000

Register name	Size/Dir.	Reset State	Description
DRAM_data_width	2 bit rw	0	Specifies the number of bits used on the DRAM interface data bus DRAM_data[31:0]. See A.5.8
row_address_bits	2 bit rw	0	Specifies the number of bits used for the row address portion of the DRAM interface address bus. See A.5.10
DRAM_enable	1 bit rw	1	Writing the value 0 in to this register forces the DRAM interface into a high impedance state.  0 will be read from this register if either the DRAM_enable signal is low or 0 has been written to the register.
CAS_strength	3 bit rw	6	These three bit registers configure the output drive strength of DRAM interface signals.  This allows the interface to be configured for various different loads.  See A.5.13
RAS_strength			
addr_strength			
DRAM_data_strength			
OEW strength			

Table A.5.3 Interface bus configuration registers

### A.5.6 Interface operation

The DRAM interface uses fast page mode. Three different types of access are supported:

- .Read
- .Write
- .Refresh

Each read or write access transfers a burst of 1 to 64 bytes to a single DRAM page address. Read and write transfers are not mixed within a single access and each successive access is treated as a random access to a new DRAM page.

Register name	Size/Dir.	Reset State	Description
refresh_interval	8 bit  rw	0	This value specifies the interval between refresh cycles in periods of 16 decoder_clock cycles. Values in the range 1..255 can be configured. The value 0 is automatically loaded after reset and forces the DRAM interface to continuously execute refresh cycles until a valid refresh interval is configured. It is recommended that refresh_interval should be configured <i>only once</i> after each reset.
no_refresh	1 bit  rw	0	Writing the value 1 to this register prevents execution of any refresh cycles.

Table A.5.4 Refresh configuration registers

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• •

```
.Access start
```

In the present invention, each access begins with an access start and is followed by one or more data transfer cycles. In addition, there is a read, write and refresh variant of both the access start and the data transfer cycle.

5        In the present invention, each access begins with an access start and is followed by one or more data transfer cycles. In addition, there is a read, write and refresh variant of both the access start and the data transfer cycle.

10        Upon completion of the last data transfer for a particular access, the interface enters its default state (see A.5.7.3) and remains in this state until a new access is ready to begin. If a new access is ready to

begin when the last access has finished, then the new access will begin immediately.

#### A.5.7.1 Access start

The access start provides the page address for the read or write transfers and establishes some initial signal conditions. In accordance with the present invention, there are three different access starts:

- .Start of read
- .Start of write
- .Start of refresh

Num.	Characteristic	Min.	Max.	Unit	Notes
5	RAS precharge period set by register RAS_falling	4	16	clk	
6	Access start duration set by register page_start_length	4	32		
7	CAS precharge length set by register CAS_falling.	1	16		
8	Fast page read or write cycle length set by the register transfer_cycle_length.	4	16		
9	Refresh cycle length set by the register refresh_cycle.	4	16		

Table A.5.5 DRAM Interface timing parameters

- a. This value must be less than RAS\_falling to ensure CAS before RAS refresh occurs.

00000000 00000000 00000000 00000000



5

#### A.5.7.2 Data transfer

10

- ```
.Fast page read cycle
.Fast page late write cycle
.Refresh cycle
```

15

20

25

#### A.5.7.3 Interface default state

30

- ```

RAS, CAS and WE high
*data and OE remain in their previous state
.addr remains stable

```

### A.5.8 Data bus width

The ~~two~~ bit register, `DRAM_data_width`, allows the width of the DRAM interface's data path to be configured. This allows the DRAM cost to be minimized when working with small picture formats.

<code>DRAM_data_width</code>	
0 <sup>a</sup>	8 bit wide data bus on <code>DRAM_data[31:24]</code> <sup>b</sup> .
1	16 bit wide data bus on <code>DRAM_data[31:16]</code> <sup>b</sup> .
2	32 bit wide data bus on <code>DRAM_data[31:0]</code> .

5

**Table A.5.6 Configuring `DRAM_data_width`**

- a. Default after reset.
- b. Unused signals are held high impedance.

#### A.5.9 row address width

The number of bits that are taken from the middle section of the 24 bit internal address in order to provide the row address is configured by the register, `row_address_bits`.

10

<code>row_address_bits</code>	Width of row address
1	10 bits on <code>DRAM_addr[9:0]</code>
2	11 bits on <code>DRAM_addr[10:0]</code>

**Table A.5.7 Configuring `row_address_bits`**

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### A.5.10-Address bits

On-chip, a 24 bit address is generated. How this address is used to form the row and column addresses depends on the width of the data bus and the number of bits selected for the row address. Some configurations do not permit all the internal address bits to be used and, therefore, produce "hidden bits").

Similarly, the row address is extracted from the middle portion of the address. Accordingly, this maximizes the rate at which the DRAM is naturally refreshed.

row address width	row address translation internal $\Rightarrow$ external	data bus width	column address translation internal $\Rightarrow$ external	
9	{14:6} $\Rightarrow$ {8:0}	8	{19:15} $\Rightarrow$ {10:6}	{5:0} $\Rightarrow$ {5:0}
		16	{20:15} $\Rightarrow$ {10:5}	{5:1} $\Rightarrow$ {4:0}
		32	{21:15} $\Rightarrow$ {10:4}	{5:2} $\Rightarrow$ {3:0}
10	{15:6} $\Rightarrow$ {9:0}	8	{19:16} $\Rightarrow$ {10:6}	{5:0} $\Rightarrow$ {5:0}
		16	{20:16} $\Rightarrow$ {10:5}	{5:1} $\Rightarrow$ {4:0}
		32	{21:16} $\Rightarrow$ {10:4}	{5:2} $\Rightarrow$ {3:0}
11	{16:6} $\Rightarrow$ {10:0}	8	{19:17} $\Rightarrow$ {10:6}	{5:0} $\Rightarrow$ {5:0}
		16	{20:17} $\Rightarrow$ {10:5}	{5:1} $\Rightarrow$ {4:0}
		32	{21:17} $\Rightarrow$ {10:4}	{5:2} $\Rightarrow$ {3:0}

**Table A.5.8 Mapping between internal and external addresses**

A.5.10-1- Low order column address bits

The least significant 4 to 6 bits of the column address are used to provide addresses for fast page mode transfers of up to 64 bytes. The number of address bits required to control these transfers will depend on the width of the data bus (see A.5.8).

#### A.5.10.2 Decoding row address to access more DRAM banks

Where only a single bank of DRAM is used, the width of the row address used will depend on the type of DRAM used.

10 Applications that require more memory than can be typically provided by a single DRAM bank, can configure a wider row address and then decode some row address bits to select a single DRAM bank.

NOTE: The row address is extracted from the middle of  
15 the internal address. If some bits of the row address are  
decoded to select banks of DRAM, then all possible values  
of these "bank select bits" must select a bank of DRAM.  
Otherwise, holes will be left in the address space.

### A.5.11 DRAM Interface enable

20 In the present invention, there are two ways to make all  
the output signals on the DRAM interface become high  
impedance, i.e., by setting the DRAM\_enable register and  
the DRAM-enable signal. Both the register and the signal  
must be at a logic 1 in order for the drivers on the DRAM  
25 interface to operate. If either is low then the interface  
is taken to high impedance.

Note: on-chip data processing is not terminated when the DRAM interface is at high impedance. Therefore, errors will occur if the chip attempts to access DRAM while the interface is at high impedance.

In accordance with the present invention, the ability to take the DRAM interface to high impedance is provided to allow other devices to test or use the DRAM controlled by the Spatial Decoder (or the Temporal Decoder) when the

Spatial Decoder (or the Temporal Decoder) is not in use. It is not intended to allow other devices to share the memory during normal operation.

#### A.5.12 Refresh

5 Unless disabled by writing to the register, no\_refresh, the DRAM interface will automatically refresh the DRAM using a  $\overline{\text{CAS}}$  before  $\overline{\text{RAS}}$  refresh cycle at an interval determined by the register, refresh\_interval.

10 The value in refresh\_interval specifies the interval between refresh cycles in periods of 16 decoder\_clock cycles. Values in the range 1.255 can be configured. The value 0 is automatically loaded after reset and forces the DRAM interface to continuously execute refresh cycles (once enabled) until a valid refresh interval is configured. It  
15 is recommended that refresh\_interval should be configured only once after each reset.

While  $\overline{\text{reset}}$  is asserted, the DRAM interface is unable to refresh the DRAM. However, the reset time required by the decoder chips is sufficiently short, so that it should be  
20 possible to reset them and then to re-configure the DRAM interface before the DRAM contents decay.

#### A.5.13 Signal strengths

The drive strength of the outputs of the DRAM interface can be configured by the user using the 3 bit registers,  
25 CAS\_strength, RAS\_strength, addr\_strength, DRAM\_data\_strength, and OEWE\_strength. The MSB of this 3 bit value selects either a fast or slow edge rate. The two less significant bits configure the output for different load capacitances.

30 The default strength after reset is 6 and this configures the outputs to take approximately 10ns to drive a signal between GND and  $V_{DD}$  if loaded with 24pF.

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strength value	Drive characteristics
0	Approx. 4 ns/V into 6 pF load
1	Approx. 4 ns/V into 12 pF load
2	Approx. 4 ns/V into 24 pF load
3	Approx. 4 ns/V into 48 pF load
4	Approx. 2 ns/V into 6 pF load
5	Approx. 2 ns/V into 12 pF load
6 <sup>a</sup>	Approx. 2 ns/V into 24 pF load
7	Approx. 2 ns/V into 48 pF load

**Table A.5.9 Output strength configurations**

**a. Default after reset**

When an output is configured appropriately for the load it is driving, it will meet the AC electrical

- 5 characteristics specified in Tables A.5.13 to A.5.16. When appropriately configured, each output is approximately matched to its load and, therefore, minimal overshoot will occur after a signal transition.

**A.5.14 Electrical specifications**

- 10 All information provided in this section is merely illustrative of one embodiment of the present invention and is included by example and not necessarily by way of limitation.

Symbol	Parameter	Min.	Max.	Units
$V_{DD}$	Supply voltage relative to GND	-0.5	6.5	V
$V_{IN}$	Input voltage on any pin	GND - 0.5	$V_{DD} - 0.5$	V
$T_A$	Operating temperature	-40	+85	°C
$T_S$	Storage temperature	-55	+150	°C

Table A.5.10 Maximum Ratings<sup>1</sup>

Table A.5.10 sets forth maximum ratings for the illustrative embodiment only. For this particular embodiment stresses below those listed in this table should  
 5 be used to ensure reliability of operation.

Symbol	Parameter	Min.	Max.	Units
$V_{DD}$	Supply voltage relative to GND	4.75	5.25	V
GND	Ground	0	0	V
$V_{IH}$	Input logic '1' voltage	2.0	$V_{DD} - 0.5$	V
$V_{IL}$	Input logic '0' voltage	GND - 0.5	0.8	V
$T_A$	Operating temperature	0	70	°C <sup>a</sup>

Table A.5.11 DC Operating conditions

a. With TBA linear ft/min transverse airflow

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## A.5.14.1 AC characteristics

Num.	Parameter	Min.	Max.	Unit	Note <sup>a</sup>
10	Cycle time	-2	+2	ns	
11	Cycle time	-2	+2	ns	
12	High pulse	-5	+2	ns	
13	Low pulse	-11	+2	ns	
14	Cycle time	-8	+2	ns	

Table A.5.13 Differences from nominal values for a strobe

- a. As will be appreciated by one of ordinary skill in the art, the driver strength of the signal must be configured appropriately for its load.

Num.	Parameter	Min.	Max.	Unit	Note <sup>a</sup>
15	Strobe to strobe delay	-3	+3	ns	
16	Low hold time	-13	+3	ns	
17	Strobe to strobe precharge e.g. tCRP, tACS, tACH, tRRH, tRPC	-9	+3	ns	
	CAS precharge pulse between any two CAS signals on wide DRAMs e.g. tCP, or between RAS rising and CAS falling e.g. tRPC	-5	+2	ns	
18	Precharge before disable	-12	+3	ns	

Table A.5.14 Differences from nominal values between two strobes

- a. The driver strength of the two signals must be configured appropriately for their loads.

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Num.	Parameter	Min.	Max.	Unit	Note <sup>a</sup>
19	Set up time	-12	+3	ns	
20	Hold time	-12	+3	ns	
21	Address access time	-12	+3	ns	
22	Next valid after strobe	-12	+3	ns	

Table A.5.15 Differences from nominal  
between a bus and a strobe

- a. The driver strength of the bus and the strobe must be configured appropriately for their loads.

Num.	Parameter	Min.	Max.	Unit	Note
23	Read data set-up time before $\overline{\text{CAS}}$ signal starts to rise	0		ns	
24	Read data hold time after $\overline{\text{CAS}}$ signal starts to go high	0		ns	

Table A.5.16 Differences from nominal  
between a bus and a strobe

When reading from DRAM, the DRAM interface samples DRAM\_data[31:0] as the CAS signals rise.

parameter		parameter		parameter	
name	number	name	number	name	number
IPC	10	IRSH	16	IRHCP	18
IRC	11	ICSH		ICPRH	19
IRP	12	IRWL		IASR	
ICP		ICWL		IASC	
ICPN		IRAC		IDS	
IRAS	13	IOAC/OE	17	IRAH	20
ICAS		ICHR		ICAH	
ICAC		ICRP		IDH	
IWP		IRCS		IAR	21
IRASP		IRCH		IAA	
IRASC	14	IRRH		IRAL	22
IACP/ICPA		IRPC		IRAD	
IRCD		ICP			
ICSR	15	IRPC			

Table A.5.17 Cross-reference between "standard" DRAM parameter names and timing parameter numbers

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## SECTION A.6 Microprocessor interface (MPI)

A standard byte wide microprocessor interface (MPI) is used on all chips in the video decoder chip-set. However, one of ordinary skill in the art will appreciate that  
 5 microprocessor interfaces of other widths may also be used. The MPI operates synchronously to various decoder chip clocks.

### A.6.1 MPI signals

Signal Name	Input / Output	Description
$\overline{\text{enable}}(1:0)$	Input	Two active low chip enables. Both must be low to enable accesses via the MPI.
$\overline{\text{rw}}$	Input	High indicates that a device wishes to read values from the video chip.  This signal should be stable while the chip is enabled.
$\text{addr}(n:0)$	Input	Address specifies one of $2^n$ locations in the chip's memory map.  This signal should be stable while the chip is enabled.
$\text{data}(7:0)$	Output	8 bit wide data I/O port. These pins are high impedance if either enable signal is high.
$\overline{\text{irq}}$	Output	An active low, open collector, interrupt request signal.

Table A.6.1 MPI interface signals

A.6.2 ~~EMI~~ electrical specifications

Symbol	Parameter	Min.	Max.	Units
$V_{DD}$	Supply voltage relative to GND	-0.5	6.5	V
$V_{IN}$	Input voltage on any pin	GND - 0.5	$V_{DD} + 0.5$	V
$T_A$	Operating temperature	-40	+85	°C
$T_S$	Storage temperature	-55	+150	°C

Table A.6.2 Absolute Maximum Ratings<sup>a</sup>

Symbol	Parameter	Min.	Max.	Units
$V_{DD}$	Supply voltage relative to GND	4.75	5.25	V
GND	Ground	0	0	V
$V_{IH}$	Input logic '1' voltage	2.0	$V_{DD} + 0.5$	V <sup>a</sup>
$V_{IL}$	Input logic '0' voltage	GND - 0.5	0.8	V <sup>(a)</sup>
$T_A$	Operating temperature	0	70	°C <sup>b</sup>

Table A.6.3 DC Operating conditions

- a. AC input parameters are measured at a 1.4V measurement level.
- b. With TBA linear ft/min transverse airflow.

[illegible]

**Table A.6.4 DC Electrical characteristics**

- $I_{OL} \leq I_{OL\max}$ .
- This is the steady state drive capability of the interface. Transient currents may be much greater.
- When asserted the open collector  $\overline{irq}$  output pulls down with an impedance of  $100\Omega$  or less.

## A.6.2.T AC characteristics

Num.	Characteristic	Min.	Max.	Unit	Notes
25	Enable low period	100		ns	
26	Enable high period	50		ns	
27	Address or $\overline{rw}$ set-up to chip enable	0		ns	
28	Address or $\overline{rw}$ hold from chip disable	0		ns	
29	Output turn-on time	20		ns	
30	Read data access time		70	ns	<sup>b</sup>
31	Read data hold time	5		ns	
32	Read data turn-off time		20		

Table A.6.5 Microprocessor interface read timing

- a. The choice, in this example, of  $\overline{enable}[0]$  to start the cycle and  $\overline{enable}[1]$  to end it is arbitrary. These signal are of equal status.
- b. The access time is specified for a maximum load of 50 pF on each of the data[7.0]. Larger loads may increase the access time.

Num.	Characteristic	Min.	Max.	Unit	Notes
33	Write data set-up time	15		ns	<sup>a</sup>
34	Write data hold time	0		ns	

Table A.6.6 Microprocessor interface write timing

- a. The choice, in this example, of  $\overline{enable}[0]$  to start the cycle and  $\overline{enable}[1]$  to end it is arbitrary. These signal are of equal status.

### A.6.3 - Interrupts

In accordance with the present invention, "event" is the term used to describe an on-chip condition that a user might want to observe. An event can indicate an error or it can be informative to the user's software.

There are two single bit registers associated with each interrupt or "event". These are the *condition event register* and the *condition mask register*.

### A.6.3.1 condition event register

10       The condition event register is a one bit read/write  
register whose value is set to one by a condition occurring  
within the circuit. The register is set to one even if the  
condition was merely transient and has now gone away. The  
register is then guaranteed to remain set to one until the  
15       user's software resets it (or the entire chip is reset).

- The register is set to zero by writing the value one
- Writing zero to the register leaves the register unaltered.
- 20 · The register must be set to zero by user software before another occurrence of this condition can be observed.
- The register will be reset to zero on reset.

25    A.6.3.2    Condition mask register

The condition mask register is one bit read/write register which enables the generation of an interrupt request if the corresponding condition event register(s) is(are) set. If the condition event is already set when 1  
30 is written to the condition mask register, an interrupt request will be issued immediately.

- The value 1 enables interrupts.
  - The register clears to zero on reset.
- Unless stated otherwise a block will stop operation



after ~~generating~~ an interrupt request and will re-start operation after either the condition event or the condition mask register is cleared.

#### A.6.3.3 Event and mask bits

5       Event bits and mask bits are always grouped into corresponding bit positions in consecutive bytes in the memory map (see Table A.9.6 and Table A.17.6). This allows interrupt service software to use the value read from the mask registers as a mask for the value in the event  
10       registers to identify which event generated the interrupt.

#### A.6.3.4 The chip event and mask

Each chip has a single "global" event bit that summarizes the event activity on the chip. The chip event register presents the OR of all the on-chip events that  
15       have 1 in their mask bit.

A 1 in the chip mask bit allows the chip to generate interrupts. A 0 in the chip mask bit prevents any on-chip events from generating interrupt requests.

Writing 1 to 0 to the chip event has no effect. It will  
20       only clear when all the events (enabled by a 1 in their mask bit) have been cleared.

#### A.6.3.5 The irq signal

The  $\overline{\text{irq}}$  signal is asserted if both the chip event bit and the chip event mask are set.

25       The  $\overline{\text{irq}}$  signal is an active low, "open collector" output which requires an off-chip pull-up resistor. When active the  $\overline{\text{irq}}$  output is pulled down by an impedance of 100 $\Omega$  or less.

I will be appreciated that pull-up resistor of  
30       approximately 4k $\Omega$  should be suitable for most applications.

### A.6.4 Accessing registers

#### A.6.4.1 Stopping circuits to enable access

In the present invention, most registers can only

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5     The value 0 in an access register indicates that the group of registers associated with that access register should not be modified. Writing 1 to an access register requests that a block be stopped. However, the block may not stop immediately and block's access register will hold the value 0 until it is stopped.

#### 15 A.6.4.2 Registers holding integers

Registers that hold integers values greater than 8 bits are split over either 2 or 4 consecutive byte locations in the memory map. The byte ordering is "big endian" as shown in Figure 55. However, no assumptions are made about the order in which bytes are written into multi-byte registers.

#### A.6.4.3 Keyholed address locations

In the present invention, certain less frequently accessed memory map locations have been placed behind



testability. Therefore, these registers have no application in the normal use of the devices and need not be accessed by normal device configuration and control software.

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## SECTION A.7 Clocks

In accordance with the present inventions, many different clocks can be identified in the video decoder system. Examples of clocks are illustrated in Figure 56.

5 As data passes between different clock regimes within the video decoder chip-set, it is resynchronized (on-chip) to each new clock. In the present invention, the maximum frequency of any input clock is 30 MHz. However, one of ordinary skill in the art will appreciate that other  
10 frequencies, including those greater than 30MHz, may also be used. On each chip, the microprocessor interface (MPI) operates asynchronously to the chip clocks. In addition, the Image Formatter can generate a low frequency audio clock which is synchronous to the decoded video's picture  
15 rate. Accordingly, this clock can be used to provide audio/video synchronization.

### A.7.1 Spatial Decoder clock signals

The Spatial Decoder has two different (and potentially asynchronous) clock inputs:

Signal Name	Input / Output	Description
coded_clock	Input	This clock controls data transfer in to the coded data port of the Spatial Decoder.  On-chip this clock controls the processing of the coded data until it reaches the coded data buffer.
decoder_clock	Input	The decoder clock controls the majority of the processing functions on the Spatial Decoder.  The decoder clock also controls the transfer of data out of the Spatial Decoder through its output port.

Table A.7.1 Spatial Decoder clocks

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### A.7.2 Temporal Decoder clock signals

The Temporal Decoder has only one clock input:

Signal Name	Input / Output	Description
decoder_clock	Input	<p>The decoder clock controls all of the processing functions on the Temporal Decoder.</p> <p>The decoder clock also controls transfer of data in to the Temporal Decoder through its input port and out via its output port.</p>

Table A.7.2 Temporal Decoder clocks

### A.7.3 Electrical specifications

Num.	Characteristic	30 MHz		Unit	Note
		Min.	Max.		
35	Clock period	33		ns	
36	Clock high period	13		ns	
37	Clock low period	13		ns	

Table A.7.3 Input clock requirements

#### Table A.7.4 Clock input conditions

The clock input signals are CMOS inputs.  $V_{IHmin}$  is approx. 70% of  $V_{DD}$  and  $V_{ILmax}$  is approx. 30% of  $V_{DD}$ . The values shown in Table A.7.4 are those for  $V_{IH}$  and  $V_{IL}$  at their respective worst case  $V_{DD}$ .  $V_{DD}=5.0\pm0.25V$ .

In the present invention, clocks used to drive the DRAM interface and the chip-to-chip interfaces are derived from the input clock signals. The timing specifications for these interfaces assume that the input clock timing is stable to within  $\pm 100$  ps.

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there are 9 user instructions, including three JTAG mandatory instructions. The extra instructions allow a degree of internal device testing to be performed, and provide additional external test flexibility. For example, all device outputs may be made to float by a simple JTAG sequence.

For full details of the facilities available and instructions on how to use the JTAG port, refer to the following JTAG Applications Notes.

#### 10 A.8.1 Connection of JTAG pins in non-JTAG systems

Signal	Direction	Description
$\overline{trst}$	Input	This pin has an internal pull-up, but must be taken low at power-up even if the JTAG features are not being used. This may be achieved by connecting $\overline{trst}$ in common with the chip reset pin $\overline{reset}$ .
$\overline{tdi}$	Input	These pins have internal pull-ups, and may be left disconnected if the JTAG circuitry is not being used.
$\overline{tms}$		
$\overline{tck}$	Input	This pin does not have a pull-up, and should be tied to ground if the JTAG circuitry is not used.
$\overline{tdo}$	Output	High impedance except during JTAG scan operations. If JTAG is not being used, this pin may be left disconnected.

Table A.8.1 How to connect JTAG inputs

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## A.8.2 Level of Conformance to IEEE 1149.1

### A.8.2.1 Rules

All rules are adhered to, although the following should be noted:

Rules	Description
3.1.1(b)	The $\overline{\text{trst}}$ pin is provided.
3.5.1(b)	Guaranteed for all public instructions (see IEEE 1149.1 5.2.1(c)).
5.2.1(c)	Guaranteed for all public instructions. For some private instructions, the TDO pin may be active during any of the states Capture-DR, Exit1-DR, Exit-2-DR & Pause-DR.
5.3.1(a)	Power on-reset is achieved by use of the $\overline{\text{trst}}$ pin.
6.2.1(e,f)	A code for the BYPASS instruction is loaded in the Test-Logic-Reset state.
7.1.1(d)	Un-allocated instruction codes are equivalent to BYPASS.
7.2.1(c)	There is no device ID register.

Table A.8.2 JTAG Rules

Rules	Description
7.8.1(b)	Single-step operation requires external control of the system clock.
7.9.1(...)	There is no RUNBIST facility.
7.11.1(...)	There is no IDCODE instruction.
7.12.1(...)	There is no USERCODE instruction.
8.1.1(b)	There is no device identification register.
8.2.1(c)	Guaranteed for all public instructions. The apparent length of the path from tdi to tdo may change under certain circumstances while private instruction codes are loaded.
8.3.1(d-i)	Guaranteed for all public instructions. Data may be loaded at times other than on the rising edge of tck while private instructions codes are loaded.
10.4.1(e)	During INTEST, the system clock pin must be controlled externally.
10.5.1(c)	During INTEST, output pins are controlled by data shifted in via tdi.

Table A.8.2 JTAG Rules

## A.8.2.2 Recommendations

Recommendation	Description
3.2.1(b)	tck is a high-impedance CMOS input.
3.3.1(c)	tms has a high impedance pull-up.
3.6.1(d)	(Applies to use of chip).
3.7.1(a)	(Applies to use of chip).
6.1.1(e)	The SAMPLE/PRELOAD instruction code is loaded during Capture-IR.
7.2.1(f)	The INTEST instruction is supported.
7.7.1(g)	Zeros are loaded at system output pins during EXTEST.
7.7.2(h)	All system outputs may be set high-impedance.
7.8.1(f)	Zeros are loaded at system input pins during INTEST.
8.1.1(d,e)	Design-specific test data registers are not publicly accessible.

Table A.8.3 Recommendations met

Recommendation	Description
10.4.1(f)	During EXTEST, the signal driven into the on-chip logic from the system clock pin is that supplied externally.

Table A.8.4 Recommendations not implemented

## A.8.2.3 Permissions

Permissions	Description
3.2.1(c)	Guaranteed for all public instructions.
6.1.1(f)	The instruction register is not used to capture design-specific information.
7.2.1(g)	Several additional public instructions are provided.
7.3.1(a)	Several private instruction codes are allocated.
7.3.1(c)	(Rule?) Such instructions codes are documented.
7.4.1(f)	Additional codes perform identically to BYPASS.
10.1.1(i)	Each output pin has its own 3-state control.
10.3.1(h)	A parallel latch is provided.
10.3.1(i,j)	During EXTEST, input pins are controlled by data shifted in via tdi.
10.5.1(d,e)	3-state cells are not forced inactive in the Test-Logic-Reset state.

Table A.8.5 Permissions met

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## SECTION A.9 Spatial Decoder

- 30 MH, operation
- Decodes MPEG, JPEG & H.261
- Coded data rates to 25 Mb/s
- 5 · Video data rates to 21 MB/s
- Flexible chroma sampling formats
- Full JPEG baseline decoding
- Glue-less DRAM interface
- Single +5V supply
- 10 · 208 pin PQFP package
- Max. power dissipation 2.5W
- Independent coded data and decoder clocks
- Uses standard page mode DRAM

15 The Spatial Decoder is a configurable VLSI decoder chip for use in a variety of JPEG, MPEG and H.261 picture and video decoding applications.

In a minimum configuration, with no off-chip DRAM, the Spatial Decoder is a single chip, high speed JPEG decoder. Adding DRAM allows the Spatial Decoder to decode JPEG  
20 encoded video pictures. 720x480, 30Hz, 4:2:2 "JPEG video" can be decoded in real-time.

With the Temporal Decoder Temporal Decoder the Spatial Decoder can be used to decode H.261 and MPEG (as well as JPEG). 704x480, 30Hz, 4:2:0 MPEG video can be decoded.

25 Again, the above values are merely illustrative, by way of example and not necessarily by way of limitation, of typical values for one embodiment in accordance with the present invention. Accordingly, those of ordinary skill in the art will appreciate that other values and/or ranges may  
30 be used.

## A.9.1 Spatial Decoder Signals

Signal Name	I/O	Pin Number	Description
coded_clock	I	182	Coded Data Port. Used to supply coded data or Tokens to the Spatial Decoder.  See sections A.10.1 and A.4.1
coded_data[7:0]	I	172, 171, 169, 168, 167, 166, 164, 163	
coded_extn	I	174	
coded_valid	I	162	
coded_accept	O	161	
byte_mode	I	176	
enable[1:0]	I	126, 127	Micro Processor Interface (MPI).  See section A.6.1
$\overline{rw}$	I	125	
addr[6:0]	I	136, 135, 133, 132, 131, 130, 128	
data[7:0]	O	152, 151, 149, 147, 145, 143, 141, 140	
$\overline{irq}$	O	154	
DRAM_data[31:0]	I/O	15, 17, 19, 20, 22, 25, 27, 30, 31, 33, 35, 38, 39, 42, 44, 47, 49, 57, 59, 61, 63, 66, 68, 70, 72, 74, 76, 79, 81, 83, 84, 85	DRAM Interface.  See section A.5.2
DRAM_addr[10:0]	O	184, 186, 188, 189, 192, 193, 195, 197, 199, 200, 203	
RAS	O	11	
$\overline{CAS}$ [3:0]	O	2, 4, 6, 8	
$\overline{WE}$	O	12	
$\overline{OE}$	O	204	
DRAM_enable	I	112	
out_data[8:0]	O	88, 89, 90, 92, 93, 94, 95, 97, 98	Output Port.  See section A.4.1
out_extn	O	87	
out_valid	O	99	
out_accept	I	100	
txk	I	115	JTAG port.  See section A.8
txl	I	116	
txo	O	120	
tms	I	117	
$\overline{trst}$	I	121	

Table A.9.1 Spatial Decoder signals

Signal Name	I/O	Pin Number	Description
decoder_clock	I	177	The main decoder clock. See section A.7
reset	I	160	Reset.

Table A.9.1 Spatial Decoder signals (contd)

Signal Name	I/O	Pin Num.	Description
tph0ish	I	122	If override = 1 then tph0ish and tph1ish are inputs for the on-chip two phase clock.
tph1ish	I	123	
override	I	110	For normal operation set override = 0. tph0ish and tph1ish are ignored (so connect to GND or V <sub>DD</sub> ).
chiptest	I	111	Set chiptest = 0 for normal operation.
tloop	I	114	Connect to GND or V <sub>DD</sub> during normal operation.
ramtest	I	109	If ramtest = 1 test of the on-chip RAMs is enabled. Set ramtest = 0 for normal operation.
pliselect	I	178	If pliselect = 0 the on-chip phase locked loops are disabled. Set pliselect = 1 for normal operation.
ti	I	180	Two clocks required by the DRAM interface during test operation. Connect to GND or V <sub>DD</sub> during normal operation.
tq	I	179	
pdout	O	207	These two pins are connections for an external filter for the phase lock loop.
pdin	I	206	

Table A.9.2 Spatial Decoder Test signals

Signal Name	Pin	Signal Name	Pin	Signal Name	Pin	Signal Name	Pin
nc	208	nc	156	nc	104	nc	52
test pin	207	nc	155	nc	103	nc	51
test pin	206	$\overline{\text{irq}}$	154	nc	102	nc	50
GND	205	nc	153	VDD	101	DRAM_data[15]	49
OE	204	data[7]	152	out_accept	100	nc	48
DRAM_addr[0]	203	data[6]	151	out_valid	99	DRAM_data[16]	47
VDD	202	nc	150	out_data[0]	98	nc	46
nc	201	data[5]	149	out_data[1]	97	GND	45
DRAM_addr[1]	200	nc	148	GND	96	DRAM_data[17]	44
DRAM_addr[2]	199	data[4]	147	out_data[2]	95	nc	43
GND	198	GND	146	out_data[3]	94	DRAM_data[18]	42
DRAM_addr[3]	197	data[3]	145	out_data[4]	93	VDD	41
nc	196	nc	144	out_data[5]	92	nc	40
DRAM_addr[4]	195	data[2]	143	VDD	91	DRAM_data[19]	39
VDD	194	nc	142	out_data[6]	90	DRAM_data[20]	38
DRAM_addr[5]	193	data[1]	141	out_data[7]	89	nc	37
DRAM_addr[6]	192	data[0]	140	out_data[8]	88	GND	36
nc	191	nc	139	out_extn	87	DRAM_data[21]	35
GND	190	VDD	138	GND	86	nc	34
DRAM_addr[7]	189	nc	137	DRAM_data[0]	85	DRAM_data[22]	33
DRAM_addr[8]	188	addr[6]	136	DRAM_data[1]	84	VDD	32
VDD	187	addr[5]	135	DRAM_data[2]	83	DRAM_data[23]	31
DRAM_addr[9]	186	GND	134	VDD	82	DRAM_data[24]	30
nc	185	addr[4]	133	DRAM_data[3]	81	nc	29
DRAM_addr[10]	184	addr[3]	132	nc	80	GND	28
GND	183	addr[2]	131	DRAM_data[4]	79	DRAM_data[25]	27
coded_clock	182	addr[1]	130	GND	78	nc	25
VDD	181	VDD	129	nc	77	DRAM_data[26]	25
test pin	180	addr[0]	128	DRAM_data[5]	76	nc	24
test pin	179	enable[0]	127	nc	75	VDD	23
test pin	178	enable[1]	126	DRAM_data[6]	74	DRAM_data[27]	22
decoder_clock	177	$\overline{\text{rw}}$	125	VDD	73	nc	21
byte_mode	176	GND	124	DRAM_data[7]	72	DRAM_data[28]	20
GND	175	test pin	123	nc	71	DRAM_data[29]	19
coded_extn	174	test pin	122	DRAM_data[8]	70	GND	18

Table A.9.3 Spatial Decoder Pin Assignments



Signal Name	Pin	Signal Name	Pin	Signal Name	Pin	Signal Name	Pin
nc	208	nc	156	nc	104	nc	52
test pin	207	nc	155	nc	103	nc	51
test pin	206	$\overline{\text{irq}}$	154	nc	102	nc	50
GND	205	nc	153	VDD	101	DRAM_data[15]	49
OE	204	data[7]	152	out_accept	100	nc	48
DRAM_addr[0]	203	data[6]	151	out_valid	99	DRAM_data[16]	47
VDD	202	nc	150	out_data[C]	98	nc	46
nc	201	data[5]	149	out_data[1]	97	GND	45
DRAM_addr[1]	200	nc	148	GND	96	DRAM_data[17]	44
DRAM_addr[2]	199	data[4]	147	out_data[2]	95	nc	43
GND	198	GND	146	out_data[3]	94	DRAM_data[18]	42
DRAM_addr[3]	197	data[3]	145	out_data[4]	93	VDD	41
nc	196	nc	144	out_data[5]	92	nc	40
DRAM_addr[4]	195	data[2]	143	VDD	91	DRAM_data[19]	39
VDD	194	nc	142	out_data[6]	90	DRAM_data[20]	38
DRAM_addr[5]	193	data[1]	141	out_data[7]	89	nc	37
DRAM_addr[6]	192	data[0]	140	out_data[8]	88	GND	36
nc	191	nc	139	out_extn	87	DRAM_data[21]	35
GND	190	VDD	138	GND	86	nc	34
DRAM_addr[7]	189	nc	137	DRAM_data[0]	85	DRAM_data[22]	33
DRAM_addr[8]	188	addr[6]	136	DRAM_data[1]	84	VDD	32
VDD	187	addr[5]	135	DRAM_data[2]	83	DRAM_data[23]	31
DRAM_addr[9]	186	GND	134	VDD	82	DRAM_data[24]	30
nc	185	addr[4]	133	DRAM_data[3]	81	nc	29
DRAM_addr[10]	184	addr[3]	132	nc	80	GND	28
GND	183	addr[2]	131	DRAM_data[4]	79	DRAM_data[25]	27
coded_clock	182	addr[1]	130	GND	78	nc	26
VDD	181	VDD	129	nc	77	DRAM_data[26]	25
test pin	180	addr[0]	128	DRAM_data[5]	76	nc	24
test pin	179	enable[0]	127	nc	75	VDD	23
test pin	178	enable[1]	126	DRAM_data[6]	74	DRAM_data[27]	22
decoder_clock	177	$\overline{\text{rw}}$	125	VDD	73	nc	21
byte_mode	176	GND	124	DRAM_data[7]	72	DRAM_data[28]	20
GND	175	test pin	123	nc	71	DRAM_data[29]	19
coded_extn	174	test pin	122	DRAM_data[8]	70	GND	18

Table A.9.3 Spatial Decoder Pin Assignments

Signal Name	Pin	Signal Name	Pin	Signal Name	Pin	Signal Name	Pin
nc	173	$\overline{rst}$	121	GND	69	DRAM_data[30]	17
coded_data[7]	172	tdo	120	DRAM_data[9]	68	nc	16
coded_data[6]	171	nc	119	nc	67	DRAM_data[31]	15
VDD	170	VDD	118	DRAM_data[10]	66	VDD	14
coded_data[5]	169	tms	117	VDD	65	nc	13
coded_data[4]	168	tdi	116	nc	64	$\overline{WE}$	12
coded_data[3]	167	tck	115	DRAM_data[11]	63	$\overline{RAS}$	11
coded_data[2]	166	test pin	114	nc	62	nc	10
GND	165	GND	113	DRAM_data[12]	61	GND	9
coded_data[1]	164	DRAM_enable	112	GND	60	$\overline{CAS}[0]$	8
coded_data[0]	163	test pin	111	DRAM_data[13]	59	nc	7
coded_valid	162	test pin	110	nc	58	$\overline{CAS}[1]$	6
coded_accept	161	test pin	109	DRAM_data[14]	57	VDD	5
reset	160	nc	108	VDD	56	$\overline{CAS}[2]$	4
VDD	159	nc	107	nc	55	nc	3
nc	158	nc	106	nc	54	$\overline{CAS}[3]$	2
nc	157	nc	105	nc	53	nc	1

Table A.9.3 Spatial Decoder Pin Assignments (contd)

## A.9.1.1 "nc" no connect pins

The pins labeled nc in Table A.9.3 are not currently used these pins should be left unconnected.

5 A.9.1.2  $V_{DD}$  and GND pins

As will be appreciated by one of ordinary skill in the art, all the  $V_{DD}$  and GND pins provided should be connected to the appropriate power supply. Correct device operation

### A.9.1.3 Test pin connections for normal operation

5

Pin number	Connection
	Connect to GND for normal operation
	Connect to $V_{DD}$ for normal operation
	Leave Open Circuit for normal operation

Table A.9.4 Default test pin connections

#### A.9.1.4 JTAG pins for normal operation

See section A.8.1.

## A.9.2 Spatial Decoder memory map

Addr. (hex)	Register Name	See table
0x00 ... 0x03	Interrupt service area	A.9.6
0x04 ... 0x07	Input circuit registers	A.9.7
0x08 ... 0x0F	Start code detector registers	
0x10 ... 0x15	Buffer start-up control registers	A.9.8
0x16 ... 0x17	Not used	
0x18 ... 0x23	DRAM interface configuration registers	A.9.9
0x24 ... 0x26	Buffer manager access and keyhole registers	A.9.10
0x27	Not used	
0x28 ... 0x2F	Huffman decoder registers	A.9.13
0x30 ... 0x39	Inverse quantiser registers	A.9.14
0x3A ... 0x3B	Not used	
0x3C	Reserved	
0x3D ... 0x3F	Not used	
0x40 ... 0x7F	Test registers	

Table A.9.5 Overview of Spatial Decoder memory map

002707 02F68960

Addr. (hex)	Bit num.	Register Name	Page references
0x00	7	chip_event CED_EVENT_0	
	6	not used	
	5	illegal_length_count_event SCD_ILLEGAL_LENGTH_COUNT	
	4	reserved may read 1 or 0 SCD_JPEG_OVERLAPPING_START	
	3	overlapping_start_event SCD_NON_JPEG_OVERLAPPING_START	
	2	unrecognised_start_event SCD_UNRECOGNISED_START	
	1	stop_after_picture_event SCD_STOP_AFTER_PICTURE	
	0	non_aligned_start_event SCD_NON_ALIGNED_START	
0x01	7	chip_mask CED_MASK_0	
	6	not used	
	5	illegal_length_count_mask	
	4	reserved write 0 to this location SCD_JPEG_OVERLAPPING_START	
	3	non_jpeg_overlapping_start_mask	
	2	unrecognised_start_mask	
	1	stop_after_picture_mask	
	0	non_aligned_start_mask	
0x02	7	idct_too_few_event IDCT_DEFF_NUM	
	6	idct_too_many_event IDCT_SUPER_NUM	
	5	accept_enable_event BS_STREAM_END_EVENT	
	4	target_met_event BS_TARGET_MET_EVENT	
	3	counter_flushed_too_early_event BS_FLUSH_BEFORE_TARGET_MET_EVENT	
	2	counter_flushed_event BS_FLUSH_EVENT	
	1	parser_event DEMUX_EVENT	
	0	huffman_event HUFFMAN_EVENT	

Table A.9.6 Interrupt service area registers

Addr. (hex)	Bit num.	Register Name	Page references
0x03	7	ldct_too_few_mask	
	6	ldct_too_many_mask	
	5	accept_enable_mask	
	4	target_met_mask	
	3	counter_flushed_too_early_mask	
	2	counter_flushed_mask	
	1	parser_mask	
	0	huffman_mask	

Table A.9.6 Interrupt service area registers (contd)

00000000 00000000 00000000 00000000

Addr. (hex)	Bit num.	Register Name	Page references
0x04	7	coded_busy	
	6	enable_mpi_input	
	5	coded_extn	
	4:0	not used	
0x05	7:0	coded_data	
0x06	7:0	not used	
0x07	7:0	not used	
0x08	7:1	not used	
	0	start_code_detector_access also input_circuit_access <i>CED_SCD_ACCESS</i>	
0x09	7:4	not used <i>CED_SCD_CONTROL</i>	
	3	stop_after_picture	
	2	discard_extension_data	
	1	discard_user_data	
	0	ignore_non_aligned	
0x0A	7:5	not used <i>CED_SCD_STATUS</i>	
	4	insert_sequence_start	
	3	discard_all_data	
	2:0	start_code_search	

Table A.9.7 Start code detector and input circuit registers

Addr. (hex)	Bit num.	Register Name	Page references
0x0B	7:0	Test register length_count	
0x0C	7:0		
0x0D	7:2	not used	
	1:0	start_code_detector_coding_standard	
0x0E	7:0	start_value	
0x0F	7:4	not used	
	3:0	picture_number	

Table A.9.7 Start code detector and input circuit registers (contd)

Addr. (hex)	Bit num.	Register Name	Page references
0x10	7:1	not used	
	0	startup_access CED_BS_ACCESS	
0x11	7:3	not used	
	2:0	bit_count_prescale CED_BS_PRESCALE	
0x12	7:0	bit_count_target CED_BS_TARGET	
0x13	7:0	bit_count CED_BS_COUNT	
0x14	7:1	not used	
	0	offchip_queue CED_BS_QUEUE	
0x15	7:1	not used	
	0	enable_stream CED_BS_ENABLE_NXT_STM	

Table A.9.8 Buffer start-up registers



Addr. (hex)	Bit num.	Register Name	Page references
0x18	7:5	not used	
	4:0	page_start_length <i>CED_IT_PAGE_START_LENGTH</i>	
0x19	7:4	not used	
	3:0	read_cycle_length	
0x1A	7:4	not used	
	3:0	write_cycle_length	

Table A.9.9 DRAM interface configuration registers

002F0F 02F5850

Addr. (hex)	Bit num.	Register Name	Page references
0x1B	7:4	not used	
	3:0	refresh_cycle_length	
0x1C	7:4	not used	
	3:0	CAS_falling	
0x1D	7:4	not used	
	3:0	RAS_falling	
0x1E	7:1	not used	
	0	interface_timing_access	
0x1F	7:0	refresh_interval	
0x20	7	not used	
	6:4	DRAM_addr_strength[2:0]	
	3:1	CAS_strength[2:0]	
	0	RAS_strength[2]	
0x21	7:6	RAS_strength[1:0]	
	5:3	OEWE_strength[2:0]	
	2:0	DRAM_data_strength[2:0]	
0x22	7	ACCESS bit for pad strength etc. ?not usedCED_DRAM_CONFIGURE	
	6	zero_buffers	
	5	DRAM_enable	
	4	no_refresh	
	3:2	row_address_bits[1:0]	
	1:0	DRAM_data_width[1:0]	
0x23	7:0	Test registers CED_PLL_RES_CONFIG	

Table A.9.9 DRAM interface configuration registers (contd)

Addr. (hex)	Bit num.	Register Name	Page references
0x24	7:1	not used	
	0	buffer_manager_access	
0x25	7:6	not used	
	5:0	buffer_manager_keyhole_address	
0x26	7:0	buffer_manager_keyhole_data	

Table A.9.10 Buffer manager access and keyhole registers

Addr. (hex)	Bit num.	Register Name	Page references
0x00	7:0	not used	
0x01	7:2		
	1:0	cdb_base	
0x02	7:0		
0x03	7:0		
0x04	7:0		
0x05	7:2	cdb_length	
	1:0		
0x06	7:0		
0x07	7:0		
0x08	7:0	not used	
0x09	7:0	cdb_read	
0x0A	7:0		
0x0B	7:0		
0x0C	7:0	not used	
0x0D	7:0	cdb_number	
0x0E	7:0		
0x0F	7:0		
0x10	7:0	not used	
0x11	7:0	tb_base	
0x12	7:0		
0x13	7:0		
0x14	7:0	not used	
0x15	7:0	tb_length	
0x16	7:0		
0x17	7:0		
0x18	7:0	not used	
0x19	7:0	tb_read	
0x1A	7:0		
0x1B	7:0		
0x1C	7:0	not used	
0x1D	7:0	tb_number	
0x1E	7:0		
0x1F	7:0		

Table A.9.11 Buffer manager extended address space

00000000 00000000 00000000 00000000

Addr. (hex)	Bit num.	Register Name	Page references
0x20	7:0	not used	
0x21	7:0	buffer_limit	
0x22	7:0		
0x23	7:0		
0x24	7:4	not used	
	3	cdb_full	
	2	cdb_empty	
	1	tb_full	
	0	tb_empty	

Table A.9.11 Buffer manager extended address space (contd)

Addr. (hex)	Bit num.	Register Name	Page references
0x28	7	demux_access CED_H_CTRL[7]	
	6:4	huffman_error_code[2:0] CED_H_CTRL[6:4]	
	3:0	private huffman control bits [3] selects special CBP, [2] selects 4/8 bit fixed length CBP	
0x29	7:0	parser_error_code CED_H_DMUX_ERR	
0x2A	7:4	not used	
	3:0	demux_keyhole_address	
0x2B	7:0	CED_H_KEYHOLE_ADDR	
0x2C	7:0	demux_keyhole_data CED_H_KEYHOLE	
0x2D	7	dummy_last_picture CED_H_ALU_REG0, r_dummy_last_frame_bit	
	6	field_info CED_H_ALU_REG0, r_field_info_bit	
	5:1	not used	
	0	continue CED_H_ALU_REG0, r_continue_bit	
0x2E	7:0	rom_revision CED_H_ALU_REG1	
0x2F	7:0	private register	

Table A.9.12 Video demux registers

Addr. (hex)	Bit num.	Register Name	Page references
0x2F	7	CED_H_TRACE_EVENT write 1 to single step, one will be read when the step has been completed	
	6	CED_H_TRACE_MASK set to one to enter single step mode	
	5	CED_H_TRACE_RST partial reset when sequenced 1,0	
	4:0	not used	

Table A.9.12 Video demux registers (contd)

002F0F " 02F6860

Addr. (hex)	Bit num.	Register Name	Page references
0x00 0x0F	7:0	not used	
0x10 0x11	7:0	horiz_pels <i>r_horz_pels</i>	
0x12 0x13	7:0	vert_pels <i>r_vert_pels</i>	
0x14	7:2	not used	
	1:0	buffer_size <i>r_buffer_size</i>	
0x15	7:0		
0x16	7:4	not used	
	3:0	pel_aspect <i>r_pel_aspect</i>	
0x17	7:2	not used	
	1:0	bit_rate <i>r_bit_rate</i>	
0x18 0x19	7:0		
0x1A	7:4	not used	
	3:0	pic_rate <i>r_pic_rate</i>	
0x1B	7:1	not used	
	0	constrained <i>r_constrained</i>	
0x1C	7:0	picture_type	
0x1D	7:0	h261_pic_type	

Table A.9.13 Video demux extended address space (Sheet 1 of 8)

Addr. (hex)	Bit num.	Register Name	Page references
0x1E	7:2	not used	
	1:0	broken_closed	
0x1F	7:5	not used	
	4:0	prediction_mode	
0x20	7:0	vbr_delay	
0x21	7:0		
0x22	7:0	private register MPEG full_pel_fwd, JPEG pending_frame_change	
0x23	7:0	private register MPEG full_pel_bwd, JPEG restart_index	
0x24	7:0	private register horiz_mb_copy	
0x25	7:0	pic_number	
0x26	7:1	not used	
	1:0	max_h	
0x27	7:1	not used	
	1:0	max_v	
0x28	7:0	private register scratch1	
0x29	7:0	private register scratch2	
0x2A	7:0	private register scratch3	
0x2B	7:0	MPEG unused1, H261 ingob	
0x2C	7:0	private register MPEG first_group, JPEG first_scan	
0x2D	7:0	private register MPEG in_picture	
0x2E	7	dummy_last_picture_r_rom_control	
	6	field_info	
	5:1	not used	
	0	continue	
0x2F	7:0	rom_revision	
0x30	7:2	not used	
	1:0	dc_huff_0	
0x31	7:2	not used	
	1:0	dc_huff_1	
0x32	7:2	not used	
	1:0	dc_huff_2	

Table A.9.13 Video demux extended address space (Sheet 2 of 8)

Addr. (hex)	Bit num.	Register Name	Page references
0x33	7:2	not used	
	1:0	dc_huff_3	
0x34	7:2	not used	
	1:0	ac_huff_0	
0x35	7:2	not used	
	1:0	ac_huff_1	
0x36	7:2	not used	
	1:0	ac_huff_2	
0x37	7:2	not used	
	1:0	ac_huff_3	
0x38	7:2	not used	
	1:0	tq_0 r_lq_0	
0x39	7:2	not used	
	1:0	tq_1 r_lq_1	
0x3A	7:2	not used	
	1:0	tq_2 r_lq_2	
0x3B	7:2	not used	
	1:0	tq_3 r_lq_3	
0x3C	7:0	component_name_0 r_c_0	
0x3D	7:0	component_name_1 r_c_1	
0x3E	7:0	component_name_2 r_c_2	
0x3F	7:0	component_name_3 r_c_3	
0x40 0x63	7:0	private registers	
0x40	7:0	r_dc_pred_0	
0x41	7:0		
0x42	7:0	r_dc_pred_1	
0x43	7:0		
0x44	7:0	r_dc_pred_2	
0x45	7:0		
0x46	7:0	r_dc_pred_3	
0x47	7:0		
0x48 0x4F	7:0	not used	

Table A.9.13 Video demux extended address space (Sheet 3 of 8)



Addr. (hex)	Bit num.	Register Name	Page references
0x50	7:0	r_prev_mhf	
0x51	7:0		
0x52	7:0	r_prev_mvf	
0x53	7:0		
0x54	7:0	r_prev_mhb	
0x55	7:0		
0x56	7:0	r_prev_mvb	
0x57	7:0		
0x58	7:0	not used	
0x5F			
0x60	7:0	r_horiz_mbcnt	
0x61	7:0		
0x62	7:0	r_vert_mbcnt	
0x63	7:0		
0x64	7:0	horiz_macroblocks r_horiz_mbs	
0x65	7:0		
0x66	7:0	vert_macroblocks r_vert_mbs	
0x67	7:0		
0x68	7:0	private register r_restart_cnt	
0x69	7:0		
0x6A	7:0	restart_interval r_restart_int	
0x6B	7:0		
0x6C	7:0	private register r_blk_h_cnt	
0x6D	7:0	private register r_blk_v_cnt	
0x6E	7:0	private register r_compid	
0x6F	7:0	max_component_id r_max_compid	
0x70	7:0	coding_standard r_coding_std	
0x71	7:0	private register r_pattern	
0x72	7:0	private register r_twd_r_size	
0x73	7:0	private register r_bwd_r_size	
0x74	7:0	not used	
0x77			
0x78	7:2	not used	
	1:0	blocks_h_0 r_blk_h_0	

Table A.9.13 Video demux extended address space (Sheet 4 of 8)

002101 "02158950

Addr. (hex)	Bit num.	Register Name	Page references
0x79	7:2	not used	
	1:0	blocks_h_1 r_blk_h_1	
0x7A	7:2	not used	
	1:0	blocks_h_2 r_blk_h_2	
0x7B	7:2	not used	
	1:0	blocks_h_3 r_blk_h_3	
0x7C	7:2	not used	
	1:0	blocks_v_0 r_blk_v_0	
0x7D	7:2	not used	
	1:0	blocks_v_1 r_blk_v_1	
0x7E	7:2	not used	
	1:0	blocks_v_2 r_blk_v_2	
0x7F	7:2	not used	
	1:0	blocks_v_3 r_blk_v_3	
0x7F 0xFF	7:0	not used	
0x100 0x10F	7:0	dc_bits_0[15:0] CED_H_KEY_DC_CPB0	
0x110 0x11F	7:0	dc_bits_1[15:0] CED_H_KEY_DC_CPB1	
0x120 0x13F	7:0	not used	
0x140 0x14F	7:0	ac_bits_0[15:0] CED_H_KEY_AC_CPB0	
0x150 0x15F	7:0	ac_bits_1[15:0] CED_H_KEY_AC_CPB1	
0x160 0x17F	7:0	not used	
0x180	7:0	dc_zssss_0 CED_H_KEY_ZSSSS_INDEX0	
0x181	7:0	dc_zssss_1 CED_H_KEY_ZSSSS_INDEX1	
0x182 0x187	7:0	not used	
0x188	7:0	ac_eob_0 CED_H_KEY_EOB_INDEX0	

Table A.9.13 Video demux extended address space (Sheet 5 of 8)

Addr. (hex)	Bit num.	Register Name	Page references
0x189	7:0	ac_eob_1 CED_H_KEY_EOB_INDEX1	
0x18A	7:0	not used	
0x18B			
0x18C	7:0	ac_zrl_0 CED_H_KEY_ZRL_INDEX0	
0x18D	7:0	ac_zrl_1 CED_H_KEY_ZRL_INDEX1	
0x18E	7:0	not used	
0x1FF			
0x200	7:0	ac_huffval_0[161:0] CED_H_KEY_AC_ITOD_0	
0x2AF			
0x2B0	7:0	dc_huffval_0[11:0] CED_H_KEY_OC_ITOD_0	
0x2BF			
0x2C0	7:0	not used	
0x2FF			
0x300	7:0	ac_huffval_1[161:0] CED_H_KEY_AC_ITOD_1	
0x3AF			
0x3B0	7:0	dc_huffval_1[11:0] CED_H_KEY_DC_ITOD_1	
0x3BF			
0x3C0	7:0	not used	
0x7FF			
0x800	7:0	private registers	
0xAC F			
0x800	7:0	CED_KEY_TCOEFF_CPS	
0x80F			
0x810	7:0	CED_KEY_CBP_CPS	
0x81F			
0x820	7:0	CED_KEY_MSA_CPS	
0x82F			
0x830	7:0	CED_KEY_MVD_CPS	
0x83F			
0x840	7:0	CED_KEY_MTYPE_I_CPS	
0x84F			

Table A.9.13 Video demux extended address space (Sheet 6 of 8)

Addr. (Hex)	Bit num.	Register Name	Page references
0x850 0x85F	7:0	CED_KEY_MTYPE_P_CPB	
0x860 0x86F	7:0	CED_KEY_MTYPE_B_CPB	
0x870 0x88F	7:0	CED_KEY_MTYPE_H261_CPB	
0x880 0x900	7:0	not used	
0x901	7:0	CED_KEY_HDSTROM_0	
0x902	7:0	CED_KEY_HDSTROM_1	
0x903 0x90F	7:0	CED_KEY_HDSTROM_2	
0x910 0xAB F	7:0	not used	
0xAC 0	7:0	CED_KEY_DMx_WORD_0	
0xAC 1	7:0	CED_KEY_DMx_WORD_1	
0xAC 2	7:0	CED_KEY_DMx_WORD_2	
0xAC 3	7:0	CED_KEY_DMx_WORD_3	
0xAC 4	7:0	CED_KEY_DMx_WORD_4	
0xAC 5	7:0	CED_KEY_DMx_WORD_5	
0xAC 6	7:0	CED_KEY_DMx_WORD_6	
0xAC 7	7:0	CED_KEY_DMx_WORD_7	

Table A.9.13 Video demux extended address space (Sheet 7 of 8)

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Addr. (hex)	Bit num.	Register Name	Page references
0xAC 8	7:0	CED_KEY_DMx_WORD_8	
0xAC 9	7:0	CED_KEY_DMx_WORD_9	
0xAC A 0xAC B	7:0	not used	
0xAC C	7:0	CED_KEY_DMx_AINCR	
0xAC D	7:0		
0xAC E	7:0	CED_KEY_DMx_CC	
0xAC F	7:0		

Table A.9.13 Video demux extended address space (Sheet 8 of 8)

Addr. (hex)	Bit num.	Register Name	Page references
	7:1	not used	
0x30	7:1	not used	
	0	iq_access	
0x31	7:2	not used	
	1:0	iq_coding_standard	
0x32	7:5	not used	
	4:0	test register iq_scale	
0x33	7:2	not used	
	1:0	test register iq_component	
0x34	7:2	not used	
	1:0	test register inverse_quantiser_prediction_mode	
0x35	7:0	test register jpeg_indirection	

Table A.9.14 Inverse quantiser registers

Table A.9.14 Inverse quantizer registers (contd)

Table A.9.15 Iq table extended address space

## SECTION A.10 Coded data input

The system in accordance with the present invention, must know what video standard is being input for processing. Thereafter, the system can accept either pre-existing Tokens or raw byte data which is then placed into Tokens by the Start Code Detector.

Consequently, coded data and configuration Tokens can be supplied to the Spatial Decoder via two routes:

- The coded data input port
- 10 · The microprocessor interface (MPI)

The choice over which route(s) to use will depend upon the application and system environment. For example, at low data rates it might be possible to use a single microprocessor to both control the decoder chip-set and to do the system bitstream de-multiplexing. In this case, it may be possible to do the coded data input via the MPI. Alternatively, a high coded data rate might require that coded data be supplied via the coded data port.

In some applications it may be appropriate to employ a mixture of MPI and coded data port input.

## A.10.1 The coded data port

Signal Name	Input / Output	Description
coded_clock	Input	A clock operating at up to 30 MHz controlling the operation of the input circuit.
coded_data(7:0]	Input	The standard 11 wires required to implement a Token Port transferring 8 bit data values. See section A.4 for an electrical description of this interface.
coded_extn	Input	
coded_valid	Input	
coded_accept	Output	Circuits off-chip must package the coded data into Tokens.
byte_mode	Input	When high this signal indicates that information is to be transferred across the coded data port in <i>byte mode</i> rather than <i>Token mode</i> .

Table A.10.1 Coded data port signals



The ~~coded~~ data port in accordance with the present invention, can be operated in two modes: *Token mode* and *byte mode*.

#### A.10.1.1 Token mode

5 In the present invention, if `byte_mode` is low, then the coded data port operates as a Token Port in the normal way and accepts Tokens under the control of `coded_valid` and `coded_accept`. See section A.4 for details of the electrical operation of this interface.

10 The signal `byte_mode` is sampled at the same time as data `[7:0]`, `coded_extn` and `coded_valid`, i.e., on the rising edge of `coded_clock`.

#### A.10.1.2 Byte mode

If, however, `byte_mode` is high, then a byte of data is  
15 transferred on data`[7:0]` under the control of the two wire interface control signals `coded_valid` and `coded_accept`. In this case, `coded_extn` is ignored. The bytes are subsequently assembled on-chip into DATA Tokens until the input mode is changed.

- 20
- 1) First word ("Head") of Token supplied in token mode.
  - 2) Last word of Token supplied (`coded_extn` goes low).
  - 3) First byte of data supplied in byte mode. A new DATA Token is automatically created on-chip.

#### A.10.2 Supplying data via the MPI

25 Tokens can be supplied to the Spatial decoder via the MPI by accessing the coded data input registers.

##### A.10.2.1 Writing Tokens via the MPI

The coded data registers of the present invention are grouped into two bytes in the memory map to allow for  
30 efficient data transfer. The 8 data bits, `coded_data[7:0]`, are in one location and the control registers, `coded_busy`, `enable_mpi_input` and `coded_extn` are in a second location.

(See Table A.9.7).

When configured for Token input via the MPI, the current Token is extended with the current value of coded\_extn each time a value is written into coded\_data[7:0]. Software is responsible for setting coded\_extn to 0 before the last word of any Token is written to coded\_data[7:0].

For example, a DATA Token is started by writing 1 into coded\_extn and then 0x04 into coded\_data[7:0]. The start of this new DATA Token then passes into the Spatial Decoder for processing.

Each time a new 8 bit value is written to coded\_data[7:0], the current Token is extended. Coded\_extn need only be accessed again when terminating the current Token, e.g. to introduce another Token. The last word of the current Token is indicated by writing 0 to coded\_extn followed by writing the last word of the current Token into coded\_data[7:0].

Register name	Size/Dir.	Reset State	Description
coded_extn	1 rw	x	Tokens can be supplied to the Spatial Decoder via the MPI by writing to these registers.
coded_data[7:0]	8 w	x	
coded_busy	1 r	1	The state of this registers indicates if the Spatial Decoder is able to accept Tokens written into coded_data[7:0].  The value 1 indicates that the interface is busy and unable to accept data. Behaviour is undefined if the user tries to write to coded_data[7:0] when coded_busy = 1
enable_mpi_input	1 rw	0	The value in this function enable registers controls whether coded data input to the Spatial Decoder is via the coded data port (0) or via the MPI (1).

Table A.10.2 Coded data input registers

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### A.10.3 Switching between input modes

5

Table A.10.3 Switching data input modes

Previous mode	Next Mode	Behaviour
Token	Byte	The off-chip circuitry supplying the Token in Token mode is responsible for completing the Token (i.e. with the extn bit of the last byte of information set to 0) before selecting byte mode.
	MPI input	Access to input via the MPI will not be granted (i.e. coded_busy will remain set to 1) until the off-chip circuitry supplying the Token in Token mode has completed the Token (i.e. with the extn bit of the last byte of information set to 0).
MPI input	Byte	The control software must have completed the Token (i.e. with the extn bit of the last byte of information set to 0) before enable_mpi_input is set to 0.
	MPI input	

Table A.10.3 Switching data input modes (contd)

The first byte supplied in byte mode causes a DATA Token header to be generated on-chip. Any further bytes transferred in byte mode are thereafter appended to this DATA Token until the input mode changes. Recall, DATA Tokens can contain as many bits as are necessary.

The MPI register bit, coded busy, and the signal, coded\_accept, indicate on which interface the Spatial decoder is willing to accept data. Correct observation of these signals ensures that no data is lost.

#### A.10.4 Rate of accepting coded data

In the present invention, the input circuit passes Tokens to the Start Code Detector (see section A.11). The Start code Detector analyses data in the DATA Tokens bit serially. The Detector's normal rate of

Accordingly, it will typically decode a byte of coded data every 8 cycles of coded\_clock. However, extra processing cycles are occasionally required, e.g., when a non-DATA

5 Token is supplied or when a start code is encountered in the coded data. When such an event occurs, the Start Code Detector will, for a short time, be unable to accept more information.

After the Start Code Detector, data passes into a first  
10 logical coded data buffer. If this buffer fills, then the  
Start Code Detector will be unable to accept more  
information.

Consequently, no more coded data (or other Tokens) will be accepted on either the coded data port, or via the MPI, while the Start Code Detector is unable to accept more information. This will be indicated by the state of the signal coded accept and the register coded busy.

By using coded\_accept and/or coded\_busy, the user is guaranteed that no coded information will be lost.

20 However, as will be appreciated by one of ordinary skill in the art, the system must either be able to buffer newly arriving coded data (or stop new data for arriving) if the Spatial decoder is unable to accept data.

#### A.10.5 Coded data clock

25 In accordance with the present invention, the coded data port, the input circuit and other functions in the Spatial Decoder are controlled by coded\_clock. Furthermore, this clock can be asynchronous to the main decoder\_clock. Data transfer is synchronized to decoder clock on-chip.

## SECTION A.11 Start code detector

### A.11.1 Start codes

As is well known in the art, MPEG and H.261 coded video streams contain identifiable bit patterns called start codes. A similar function is served in JPEG by marker codes. Start/marker codes identify significant parts of the syntax of the coded data stream. The analysis of start/marker codes performed by the Start Code Detector is the first stage in parsing the coded data. The Start Code Detector is the first block on the Spatial Decoder following the input circuit.

The start/marker code patterns are designed so that they can be identified without decoding the entire bitstream. Thus, they can be used in accordance with the present invention, to help with error recovery and decoder start-up. The Start Code Detector provides facilities to detect errors in the coded data construction and to assist the start-up of the decoder.

### A.11.2 Start code detector registers

As previously discussed, many of the Start Code Detector registers are in constant use by the Start Code Detector. So, accessing these registers will be unreliable if the Start Code Detector is processing data. The user is responsible for ensuring that the Start Code Detector is halted before accessing its registers.

The register `start_code_detector_access` is used to halt the Start Code Detector and so allow access to its registers. The Start Code Detector will halt after it generates an interrupt.

There are further constraints on when the start code search and discard all data modes can be initiated. These are described in A.11.8 and A.11.5.1.

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Register name	Size/Dir.	Reset State	Description
start_code_detector_access	1 rw	0	Writing 1 to this register requests that the start code detector stop to allow access to its registers. The user should wait until the value 1 can be read from this register indicating that operation has stopped and access is possible.

**Table A.11.1 Start code detector  
registers (Sheet 1 of 5)**

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Register name	Size/Dir.	Reset State	Description
illegal_length_count_event	1 rw	0	An illegal length count event will occur if while decoding JPEG data, a length count field is found carrying a value less than 2. This should only occur as the result of an error in the JPEG data.  If the mask register is set to 1 then an interrupt can be generated and the start code detector will stop. Behaviour following an error is not predictable if this error is suppressed (mask register set to 0). See A.11.4.1
illegal_length_count_mask	1 rw	0	
jpeg_overlapping_start_event	1 rw	0	If the coding standard is JPEG and the sequence 0xFF 0xFF is found while looking for a marker code this event will occur.  This sequence is a legal stuffing sequence.  If the mask register is set to 1 then an interrupt can be generated and the start code detector will stop. See A.11.4.2
jpeg_overlapping_start_mask	1 rw	0	
overlapping_start_event	1 rw	0	If the coding standard is MPEG or H.261 and an overlapping start code is found while looking for a start code this event will occur. If the mask register is set to 1 then an interrupt can be generated and the start code detector will stop. See A.11.4.2
overlapping_start_mask	1 rw	0	

Table A.11.1 Start code detector registers (Sheet 2 of 5)

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Register name	Size/Dir.	Reset State	Description
unrecognised_start_event	1 rw	0	If an unrecognised start code is encountered this event will occur. If the mask register is set to 1 then an interrupt can be generated and the start code detector will stop.
unrecognised_start_mask	1 rw	0	
start_value	8 ro	x	<p>The start code value read from the bitstream is available in the register start_value while the start code detector is halted. See A.11.4.3</p> <p>During normal operation start_value contains the value of the most recently decoded start marker code.</p> <p>Only the 4 LSBs of start_value are used during H.261 operation. The 4 MSBs will be zero.</p>
stop_after_picture_event	1 rw	0	If the register stop_after_picture is set to 1 then a stop after picture event will be generated after the end of a picture has passed through the start code detector.
stop_after_picture_mask	1 rw	0	
stop_after_picture	1 rw	0	<p>If the mask register is set to 1 then an interrupt can be generated and the start code detector will stop. See A.11.5.1</p> <p>stop_after_picture does not reset to 0 after the end of a picture has been detected so should be cleared directly.</p>

Table A.11.1 Start code detector registers (Sheet 3 of 5)

Register name	Size/Dir.	Reset State	Description
non_aligned_start_event	1 rw	0	When ignore_non_aligned is set to 1, start codes that are not byte aligned are ignored (treated as normal data).
non_aligned_start_mask	1 rw	0	When ignore_non_aligned is set to 0, H.261 and MPEG start codes will be detected regardless of byte alignment and the non-aligned start event will be generated.
ignore_non_aligned	1 rw	0	If the mask register is set to 1 then the event will cause an interrupt and the start code detector will stop. See A.11.6  If the coding standard is configured as JPEG ignore_non_aligned is ignored and the non-aligned start event will never be generated.
discard_extension_data	1 rw	1	When these registers are set to 1 extension or user data that cannot be decoded by the Spatial Decoder is discarded by the start code detector. See A.11.3.3
discard_user_data	1 rw	1	
discard_all_data	1 rw	0	When set to 1 all data and Tokens are discarded by the start code detector. This continues until a FLUSH Token is supplied or the register is set to 0 directly.  The FLUSH Token that resets this register is discarded and not output by the start code detector. See A.11.5.1
insert_sequence_start	1 rw	1	See A.11.7

Table A.11.1 Start code detector registers (Sheet 4 of 5)

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Register name	Size/Dir	Reset State	Description
start_code_search	3 rw	5	When this register is set to 0 the start code detector operates normally. When set to a higher value the start code detector discards data until the specified type of start code is detected. When the specified start code is detected the register is set to 0 and normal operation follows. See A.11.3
start_code_detector_coding_standard	2 rw	0	This register configures the coding standard used by the start code detector. The register can be loaded directly or by using a <b>CODING_STANDARD</b> Token.  Whenever the start code detector generates a <b>CODING_STANDARD</b> Token (see A.11.7.4) it carries its current coding standard configuration. This Token will then configure the coding standard used by all other parts of the decoder chip-set. See A.21.1 and A.11.7
picture_number	4 rw	0	Each time the start code detector detects a picture start code in the data stream (or the H.261 or JPEG equivalent) a <b>PICTURE_START</b> Token is generated which carries the current value of picture_number. This register then increments.

Table A.11.1 Start code detector registers (Sheet 5 of 5)

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Register name	Size/Dir.	Reset State	Description
length_count	16 r0	0	This register contains the current value of the JPEG length count. This register is modified under the control of the coded data clock and should only be read via the MPI when the start code detector is stopped.

**Table A.11.2 Start code detector test registers**

### A.11.3 Conversion of start codes to Tokens

In normal operation the function of the Start Code Detector is to identify start codes in the data stream and to then convert them to the appropriate start code Token. In the simplest case, data is supplied to the Start code Detector in a single long DATA Token. The output of the Start Code Detector is a number of shorter DATA Tokens interleaved with start code Tokens.

Alternatively, in accordance with the present invention, the input data to the Start Code Detector could be divided up into a number of shorter DATA Tokens. There is no restriction on how the coded data is divided into DATA Tokens other than that each DATA Token must contain  $8 \times n$  bits where  $n$  is an integer.

Other Tokens can be supplied directly to the input of the Start Code Detector. In this case, the Tokens are passed through the Start Code Detector with no processing

to other stages of the Spatial Decoder. These Tokens can only be inserted just before the location of a start code in the coded data.

#### A.11.3.1 Start code formats

- 5 Three different start code formats are recognized by the Start Code Detector of the present invention. This is configured via the register, `start_code_detector_coding_standard`.

Coding Standard	Start Code Pattern (hex)	Size of start code value
MPEG	0x00 0x00 0x01 <value>	8 bit
JPEG	0xFF <value>	8 bit
H.261	0x00 0x01 <value>	4 bit

Table A.11.3 Start code formats

#### 10 A.11.3.2 Start code Token equivalents

- Having detected a start code, the Start Code Detector studies the value associated with the start code and generates an appropriate Token. In general, the Tokens are named after the relevant MPEG syntax. However, one of  
 15 ordinary skill in the art will appreciate that the Tokens can follow additional naming formats. The coding standard currently selected configures the relationship between start code value and the Token generated. This relationship is shown in Table A.11.4.

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Start code Token generated	Start Code Value			
	MPEG (hex)	H 261 (hex)	JPEG (hex)	JPEG (name)
PICTURE_START	0x00	0x00	0xDA	SOS
SLICE_START *	0x01 to 0xAF	0x01 to 0xCC	0xD0 to 0xD7	RST <sub>0</sub> to RST <sub>7</sub>
SEQUENCE_START	0xB3		0xD8	SOI
SEQUENCE_END	0xB7		0xD9	EOI
GROUP_START	0xB8		0xC0	SOF <sub>0</sub> <sup>3</sup>
USER_DATA	0xB2		0xE0 to 0xEF	APP <sub>0</sub> to APP <sub>7</sub>
			0xFE	COM
EXTENSION_DATA	0xB5		0xC8	JPG
			0xF0 to 0xF0	JPG <sub>0</sub> to JPG <sub>0</sub>
			0xC2 to 0xBF	RES
			0xC1 to 0xC8	SOF <sub>1</sub> to SOF <sub>11</sub>
			0xCC	DAC
DHT_MARKER			0xC4	DHT
DNL_MARKER			0xDC	DNL
DQT_MARKER			0xDB	DQT
DRI_MARKER			0xDD	DRI

Table A.11.4 . Tokens from start code values

- a. This Token contains an 8 bit data field which is loaded with a value determined by the start code value.
- 5 b. Indicates start of baseline DCT encoded data.

### A.11.3.3 Extended features of the coding standards

The coding standards provide a number of mechanisms to allow data to be embedded in the data stream whose use is not currently defined by the coding standard. This might be application specific "user data" that provides extra facilities for a particular manufacturer. Alternatively, it might be "extension data". The coding standards authorities reserved the right to use the extension data to add features to the coding standard in the future.

Two distinct mechanisms are employed. JPEG precedes blocks of user and extension data with marker codes. However, H.261 inserts "extra information" indicated by an extra information bit in the coded data. MPEG can use both these techniques.

In accordance with the present invention, MPEG/JPEG blocks of user and extension data preceded by start/marker codes can be detected by the Start Code Detector. H.261/MPEG "extra information" is detected by the Huffman decoder of the present invention. See A.14.7, "Receiving Extra Information".

The registers, `discard_extension_data` and `discard_user_data`, allow the Start Code Detector to be configured to discard user data and extension data. If this data is not discarded at the Start Code Detector it can be accessed when it reaches the Video Demux see A.14.6, "Receiving User and Extension data".

The Spatial Decoder of the present invention supports the baseline features of JPEG. The non-baseline features of JPEG are viewed as extension data by the Spatial Decoder. So, all JPEG marker codes that precede data for non-baseline JPEG are treated as extension data.

#### **A.11.3.4 JPEG Table definitions**

JPEG supports down loaded Huffman and quantizer tables. In JPEG data, the definition of these tables is preceded by the marker codes DNL and DQT. The Start Code Detector  
5 generates the Tokens DHT\_MARKER and DQT\_MARKER when these marker codes are detected. These Tokens indicate to the Video Demux that the DATA Token which follows contains coded data describing Huffman or quantizer table (using the formats described in JPEG).

#### **10 A.11.4 Error detection**

The Start Code Detector can detect certain errors in the coded data and provides some facilities to allow the decoder to recover after an error is detected (see A.11.8, "Start code searching").

##### **15 A.11.4.1 Illegal JPEG length count**

Most JPEG marker codes have a 16 bit length count field associated with them. This field indicates how much data is associated with this marker code. Length counts of 0 and 1 are illegal. An illegal length should only occur  
20 following a data error. In the present invention, this will generate an interrupt if illegal\_length\_count\_mask is set to 1.

Recovery from errors in JPEG data is likely to require additional application specific data due to the difficulty  
25 of searching for start codes in JPEG data (see A.11.8.1).

##### **A.11.4.2 Overlapping start/marker codes**

In the present invention, overlapping start codes should only occur following a data error. An MPEG, byte aligned, overlapping start code is illustrated in Figure 64. Here,  
30 the Start Code Detector first sees a pattern that looks like a picture start code. Next the Start Code Detector sees that this picture start code is overlapped with a group start. Accordingly, the Start Code Detector

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000



generates a overlapping start event. Furthermore, the Start Code Detector will generate an interrupt and stop if overlapping\_start\_mask is set to 1.

It is impossible to tell which of the two start codes is the correct one and which was caused by a data error. However, the Start Code Detector in accordance with the present invention, discards the first start code and will proceed decoding the second start code "as if it is correct" after the overlapping start code event has been serviced. If there are a series of overlapped start codes, the Start Code Detector will discard all but the last (generating an event for each overlapping start code).

Similar errors are possible in non byte-aligned systems (H.261 or possibly MPEG). In this case, the state of ignore\_non\_aligned must also be considered. Figure 65 illustrates an example where the first start code found is byte aligned, but it overlaps a non-aligned start code. If ignore\_non\_aligned is set to 1, then the second overlapping start code will be treated as data by the Start Code Detector and, therefore no overlapping start code event will occur. This conceals a possible data communications error. If ignore\_non\_aligned is set to 0, however the Start Code Detector will see the second, non aligned, start code and will see that it overlaps the first start code.

25    **A.11.4.3    Unrecognized start codes**

The Start Code Detector can generate an interrupt when an unrecognized start code is detected (if `unrecognized_start_mask = 1`). The value of the start code that caused this interrupt can be read from the register start value.

The start code value 0xB4 (sequence error) is used in MPEG decoder systems to indicate a channel or media error. For example, this start code may be inserted into the data by an ECC circuit if it detects an error that it was unable

to correct.

#### A.11.4.4 Sequence of event generation

In the present invention, certain coded data patterns (probably indicating an error condition) will cause more than one of the above error conditions to occur within a short space of time. Consequently, the sequence in which the Start Code Detector examines the coded data for error conditions is:

- 1) Non-aligned start codes
- 2) Overlapping start codes
- 3) Unrecognized start codes

Thus, if a non-aligned start code overlaps another, later, start code, the first event generated will be associated with the non-aligned start code. After this event has been serviced, the Start Code Detector's operation will proceed, detecting the overlapped start code a short time later.

The Start Code Detector only attempts to recognize the start code after all tests for non-aligned and overlapping start codes are complete.

#### A.11.5 Decoder start-up and shutdown

The Start Code Detector provides facilities to allow the current decoding task to be completed cleanly and for a new task to be started.

There are limitations on using these techniques with JPEG coded video as data segments can contain values that emulate marker codes (see A.11.8.1).

##### A.11.5.1 Clean end to decoding

The Start Code Detector can be configured to generate an interrupt and stop once the data for the current picture is complete. This is done by setting `stop_after_picture = 1` and `stop_after_picture_mask = 1`.

Once the end of a picture passes through the Start Code Detector, a FLUSH Token is generated (A.11.7.2),

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This section illustrates an application of some of the techniques described above. The objective is to "jump"

from ~~one~~ part of one coded video sequence to another. In this example, the filing system only allows access to "blocks" of data. This block structure might be derived from the sector size of a disc or a block error correction system. So, the position of entry and exit points in the coded video data may not be related to the filing system block structure.

The stop\_after\_picture and discard\_all\_data mechanisms allow unwanted data from the old video sequence to be discarded. Inserting a FLUSH Token after the end of the last filing system data block resets the discard\_all\_data mode. The start code search mode can then be used to discard any data in the next data block that precedes a suitable entry point.

#### 15 A.11.6 Byte alignment

As is well known in the art, the different coding schemes have quite different views about byte alignment of start/marker codes in the data stream.

For example, H.261 views communications as being bit serial. Thus, there is no concept of byte alignment of start codes. By setting ignore\_non\_aligned = 0 the Start Code Detector is able to detect start codes with any bit alignment. By setting non-aligned\_start\_mask = 0, the start code non-alignment interrupt is suppressed.

In contrast, however, JPEG was designed for a computer environment where byte alignment is guaranteed. Therefore, marker codes should only be detected when byte aligned. When the coding standard is configured as JPEG, the register ignore\_non\_aligned is ignored and the non-aligned start event will never be generated. However, setting ignore\_non\_aligned = 1 and non\_aligned\_start\_mask = 0 is recommended to ensure compatibility with future products.

MPEG, on the other hand, was designed to meet the needs of both communications (bit serial) and computer (byte

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

oriented systems. Start codes in MPEG data should normally be byte aligned. However, the standard is designed to be allow bit serial searching for start codes (no MPEG bit pattern, with any bit alignment, will look  
 5 like a start code, unless it is a start code). So, an MPEG decoder can be designed that will tolerate loss of byte alignment in serial data communications.

If a non-aligned start code is found, it will normally indicate that a communication error has previously  
 10 occurred. If the error is a "bit-slip" in a bit-serial communications system, then data containing this error will have already been passed to the decoder. This error is likely to cause other errors within the decoder. However, new data arriving at the Start Code Detector can continue  
 15 to be decoded after this loss of byte alignment.

By setting ignore\_non\_aligned = 0 and non\_aligned\_start\_mask = 1, an interrupt can be generated if a non-aligned start code is detected. The response will depend upon the application. All subsequent start codes  
 20 will be non-aligned (until byte alignment is restored). Accordingly, setting non\_aligned\_start\_mask = 0 after byte alignment has been lost may be appropriate.

	MPEG	JPEG	H.251
ignore_non_aligned	0	1	0
non_aligned_start_mask	1	0	0

Table A.11.5 Configuring for byte alignment

### **A.11.7 Automatic Token generation**

In the present invention, most of the Tokens output by the Start Code Detector directly reflect syntactic elements of the various picture and video coding standards. In addition to these "natural" Tokens, some useful "invented" Tokens are generated. Examples of these proprietary tokens are PICTURE\_END and CODING\_STANDARD. Tokens are also introduced to remove some of the syntactic differences between the coding standards and to "tidy up" under error conditions.

This automatic Token generation is done after the serial analysis of the coded data (see Figure 61, "The Start Code Detector"). Therefore the system responds equally to Tokens that have been supplied directly to the input of the Spatial Decoder via the Start Code Detector and to Tokens that have been generated by the Start Code Detector following the detection of start codes in the coded data.

#### **A.11.7.1 Indicating the end of a picture**

In general, the coding standards don't explicitly signal the end of a picture. However, the Start Code Detector of the present invention generates a PICTURE\_END Token when it detects information that indicates that the current picture has been completed.

The Tokens that cause PICTURE\_END to be generated are: SEQUENCE\_START, GROUP\_START, PICTURE\_START, SEQUENCE\_END and FLUSH.

#### **A.11.7.2 Stop after picture end option**

If the register stop\_after\_picture is set, then the Start Code Detector will stop after a PICTURE\_END Token has passed through. However, a FLUSH Token is inserted after the PICTURE\_END to "push" the tail end of the coded data through the decoder and to reset the system. See A.11.5.1.

### A.11.7.3~~3~~ Introducing sequence start for H.261

H.261 does not have a syntactic element equivalent to sequence start (see Table A.11.4). If the register insert\_sequence\_start is set, then the Start Code Detector  
 5 will ensure that there is one SEQUENCE\_START Token before the next PICTURE\_START, i.e., if the Start Code Detector does not see a SEQUENCE\_START before a PICTURE\_START, one will be introduced. No SEQUENCE\_START will be introduced if one is already present.

10 *This function should not be used with MPEG or JPEG.*

### A.11.7.4 Setting coding standard for each sequence

All SEQUENCE\_START Tokens leaving the Start Code Detector are always preceded by a CODING\_STANDARD Token. This Token is loaded with the Start Code Detector's current  
 15 coding standard. This sets the coding standard for the entire decoder chip set for each new video sequence.

### A.11.8 Start code searching

The Start Code Detector in accordance with the invention, can be used to search through a coded data  
 20 stream for a specified type of start code. This allows the decoder to re-commence decoding from a specified level within the syntax of some coded data (after discarding any data that precedes it). Applications for this include:

- start-up of a decoder after jumping into a coded data
- 25 file at an unknown position (e.g., random accessing).
- to seek to a known point in the data to assist recovery after a data error.

For example, Table A.11.6 shows the MPEG start codes searched, for different configurations of  
 30 start\_code\_search. The equivalent H.261 and JPEG start/marker codes can be seen in Table A.11.4.

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start_code_search	Start codes searched for ...
0 <sup>a</sup>	Normal operation
1	Reserved (will behave as discard data)
2	
3	sequence start

start_code_search	Start codes searched for ...
4	group or sequence start
5 <sup>b</sup>	picture, group or sequence start
6	slice, picture, group or sequence start
7	the next start or marker code

**Table A.11.6 Start code search modes**

- a. A FLUSH Token places the Start Code Detector in this search mode.
- b. This is the default mode after reset.

5       When a non-zero value is written into the  
start\_code\_search register, the Start Code Detector will  
start to discard all incoming data until the specified  
start code is detected. The start\_code\_search register  
will then reset to 0 and normal operation will continue.

10       The start code search will start immediately after a  
non-zero value is written into the start\_code\_search  
register. The result will be unpredictable if this is done  
when the Start Code Detector is actively processing data.  
So, before initiating a start code search, the Start Code  
15       Detector should be stopped so no data is being processed.  
The Start Code Detector is always in this condition if any  
of the Start Code Detector events (non-aligned start event  
etc.) has just generated an interrupt.

#### A.11.8.1 Limitations on using start code search with JPEG



Most ~~J~~PEG marker codes have a 16 bit length count field associated with them. This field indicates the length of a data segment associated with the marker code. This segment may contain values that emulate marker codes. In normal  
5 operation, the Start Code Detector doesn't look for start codes in these segments of data.

If a random access into some JPEG coded data "lands" in such a segment, the start code search mechanism cannot be used reliably. In general, JPEG coded video will require  
10 additional external information to identify entry points for random access.

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### A.12.2~~2~~ MPEG video buffer verifier

MPEG describes a "video buffer verifier" (VBV) for constant data rate systems. Using the VBV information allows the decoder to pre-fill its buffers before it starts to display pictures. Again, this pre-filling ensures that the decoder's buffers never empty during decoding.

In summary, each MPEG picture carries a `vbv_delay` parameter. This parameter specifies how long the coded data buffer of an "ideal decoder" should fill with coded data before the first picture is decoded. Having observed the start-up delay for the first picture, the requirements of all subsequent pictures will be met automatically.

MPEG, therefore, specifies the start-up requirements as a delay. However, in a constant bit rate system this delay can readily be converted to a bit count. This is the basis on which the start-up control of the Spatial Decoder of the present invention operates.

### A.12.3 Definition of a stream

In this application, the term *stream* is used to avoid confusion with the MPEG term *sequence*. *Stream* therefore means a quantity of video data that is "interesting" to an application. Hence, a stream could be many MPEG sequences or it could be a single picture.

The decoder start-up facilities described in this chapter relate to meeting the VBV requirements of the first picture in a stream. The requirements of subsequent pictures in that stream are met automatically.

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## A.12.4 Start-up control registers

Register name	Size/Dir	Reset State	Description
startup_access <i>CED_BS_ACCESS</i>	1 rw	0	Writing 1 to this register requests that the bit counter and gate opening logic stop to allow access to their configuration registers.
bit_count <i>CED_BS_COUNT</i>	8 rw	0	This bit counter is incremented as coded data leaves the start code detector. The number of bits required to increment bit_count once is approx. $2^{(\text{bit\_count\_prescale}-1)} \times 512$ .  The bit counter starts counting bits after a FLUSH Token passes through the bit counter. It is reset to zero and then stops incrementing after the bit count target has been met.
bit_count_prescale <i>CED_BS_PRESCALE</i>	3 rw	0	This register specifies the bit count target. A target met event is generated whenever the following condition becomes true:  $\text{bit\_count} \geq \text{bit\_count\_target}$
target_met_event <i>BS_TARGET_MET_EVENT</i>	1 rw	0	When the bit count target is met this event will be generated. If the mask register is set to 1 then an interrupt can be generated, however the bit counter will NOT stop processing data.
target_met_mask	1 rw	0	This event will occur when the bit counter increments to its target. It will also occur if a target value is written which is less than or equal to the current value of the bit counter. Writing 0 to bit_count_target will always generate a target met event.

Table A.12.1 Decoder start-up registers

00000000 00000000 00000000 00000000

Table A.12.1 Decoder start-up registers (contd)

Table A.12.1 Decoder start-up registers (contd)

Register name	Size/Dir.	Reset State	Description
accept_enable_event	1	0	This event indicates that a FLUSH Token has passed through the output gate (causing it to close) and that an enable was available to allow the gate to open.
SS_STREAM_END_EVENT	rw		
accept_enable_mask	1	0	If the mask register is set to 1 then an interrupt can be generated and the register enable_stream will be reset. See A.12.7.1
	rw		

Table A.12.1 Decoder start-up registers (contd)

**A.12.5 Output gate always open**

The output gate can be configured to remain open. This configuration is appropriate where still pictures are being decoded, or when some other mechanism is available to manage the start-up of the video decoder.

The following configurations are required after reset (having gained access to the start-up control logic by writing 1 to startup\_access):

- set offchip\_queue = 1
- 10 · set enable\_stream = 1
- ensure that all the decoder start-up event mask registers are set to 0 disabling their interrupts (this is the default state after reset).

(See A.12.7.1 for an explanation of why this holds the output gate open.)

**A.12.6 Basic operation**

In the present invention, basic control of the start-up logic is sufficient for the majority of MPEG video applications. In this mode, the bit counter communicates directly with the output gate. The output gate will close automatically as the end of a video stream passes through it as indicated by a FLUSH Token. The gate will remain closed until an enable is provided by the bit counter circuitry when a stream has attained its start-up bit count.

The following configurations are required after reset (having gained access to the start-up control logic by writing 1 to startup\_access):

- set bit\_count\_prescale approximately for the expected range of coded data rates
- 30 · set counter\_flushed\_too\_early\_mask = 1 to enable this error condition to be detected

Two interrupt service routines are required:

- Video Demux service to obtain the value of

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vbv\_delay for the first picture in each new stream

·Counter flushed too early service to react to this condition

- 5       The video demux (also known as the video parser) can generate an interrupt when it decodes the vbv\_delay for a new video stream (i.e., the first picture to arrive at the video demux after a FLUSH). The interrupt service routine should compute an appropriate value for bit\_count\_target
- 10      and write it. When the bit counter reaches this target, it will insert an enable into a short queue between the bit counter and the output gate. When the output gate opens it removes an enable from this queue.

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#### **A.12.6.1 Starting a new stream shortly after another finishes**

As an example, the MPEG stream which is about to finish is called A and the MPEG stream about to start is called B.  
 5 A FLUSH Token should be inserted after the end of A. This pushes the last of its coded data through the decoder and alerts the various sections of the decoder to expect a new stream.

Normally, the bit counter will have reset to zero, A  
 10 having already met its start-up conditions. After the FLUSH, the bit counter will start counting the bits in stream B. When the Video Demux has decoded the vbv\_delay from the first picture in stream B, an interrupt will be generated allowing the bit counter to be configured.

15 As the FLUSH marking the end of stream A passes through the output gate, the gate will close. The gate will remain closed until B meets its start-up conditions. Depending on a number of factors such as: the start-up delay for stream B and the depth of the buffers, it is possible that B will  
 20 have already met its start-up conditions when the output gate closes. In this case, there will be an enable waiting in the queue and the output gate will immediately open. Otherwise, stream B will have to wait until it meets its start-up requirements.

#### **25 A.12.6.2 A succession of short streams**

The capacity of the queue located between the bit counter and the output gate is sufficient to allow 3 separate video streams to have met their start-up conditions and to be waiting for a previous stream to  
 30 finish being decoded. In the present invention, this situation will only occur if very short streams are being decoded or if the off-chip buffers are very large as compared to the picture format being decoded).

In Figure 69 stream A is being decoded and the

output gate is open). Streams B and C have met their start-up conditions and are entirely contained within the buffers managed by the Spatial Decoder. Stream D is still arriving at the input of the Spatial Decoder.

5        Enables for streams B and C are in the queue. So, when stream A is completed B will be able to start immediately. Similarly C can follow immediately behind B.

If A is still passing through the output gate when D meets its start-up target an enable will be added to the queue, filling the queue. If no enables have been removed from the queue by the time the end of D passes the bit counter (i.e., A is still passing through the output gate) no new stream will be able to start through the bit counter. Therefore, coded data will be held up at the input until A completes and an enable is removed from the queue as the output gate is opened to allow B to pass through.

### A.12.7 Advanced operation

In accordance with the present invention, advanced control of the start-up logic allows user software to infinitely extend the length of the enable queue described in A.12.6, "Basic operation". This level of control will only be required where the video decoder must accommodate a series of short video streams longer than that described in A.12.6.2, "A succession of short streams".

In addition to the configuration required for Basic operation of the system, the following configurations are required after reset (having gained access to the start-up control logic by writing 1 to start up access):

```

30      · set offchip_queue = 1
      · set accept_enable_mask = 1 to enable interrupts
        when an enable has been removed from the queue
      · set target_met_mask = 1 to enable interrupts
        when a stream's bit count target is met

```

Two ~~additional~~ interrupt service routines are required:

- accept enable interrupt
- Target met interrupt

- 5      When a target met interrupt occurs, the service routine should add an enable to its off-chip enable queue.

#### A.12.7.1 Output gate logic behavior

Writing a 1 to the enable\_stream register loads an enable into a short queue.

- 10      When a FLUSH (marking the end of a stream) passes through the output gate the gate will close. If there is an enable available at the end of the queue, the gate will open and generate an accept\_enable\_event. If accept\_enable\_mask is set to one, an interrupt can be  
15      generated and an enable is removed from the end of the queue (the register enable\_stream is reset).

However, if accept\_enable\_mask is set to zero, no interrupt is generated following the accept\_enable\_event and the enable is NOT removed from the end of the queue.

- 20      This mechanism can be used to keep the output gate open as described in A.12.5.

#### A.12.8 Bit counting

- 25      The bit counter starts counting after a FLUSH Token passes through it. This FLUSH Token indicates the end of the current video stream. In this regard, the bit counter continues counting until it meets the bit count target set in the bit\_count\_target register. A target met event is then generated and the bit counter resets to zero and waits for the next FLUSH Token.

- 30      The bit counter will also stop incrementing when it reaches its maximum count (255).

#### A.12.9 Bit count prescale

In the present invention,  $2^{(\text{bit\_count\_prescale} - 1)} \times 512$  bits are

00000000 00000000 00000000 00000000

required to increment the bit counter once. Furthermore, bit\_count\_prescale is a 3 bit register that can hold a value between 0 and 7.

n	Range (bits)	Resolution (bits)
0	0 to 262144	1024
1	0 to 524288	2048
7	0 to 31457280	122880

**Table A.12.2 Example bit counter ranges**

5 The bit count is approximate, as some elements of the video stream will already have been Tokenized (e.g., the start codes) and, therefore includes non-data Tokens.

#### **A.12.10 Counter flushed too early**

10 If a FLUSH token arrives at the bit counter before the bit count target is attained, an event is generated which can cause an interrupt (if counter\_flushed\_too\_early\_mask = 1). If the interrupt is generated, then the bit counter circuit will stop, preventing further data input. It is the responsibility of the user's software to decide when to  
 15 open the output gate after this event has occurred. The output gate can be made to open by writing 0 as the bit count target. These circumstances should only arise when trying to decode video streams that last only a few pictures.

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## SECTION A.13 Buffer Management

The Spatial Decoder manages two logical data buffers: the coded data buffer (CDB) and the Token buffer (TB).

The CDB buffers coded data between the Start Code  
5 Detector and the input of the Huffman decoder. This  
provides buffering for low data rate coded video data. The  
TB buffers data between the output of the Huffman decoder  
and the input of the spatial video decoding circuits  
(inverse modeler, quantizer and DCT). This second logical  
10 buffer allows processing time to include a spread so as to  
accommodate processing pictures having varying amounts of  
data.

Both buffers are physically held in a single off-chip  
DRAM array. The addresses for these buffers are generated  
15 by the buffer manager.

### A.13.1 Buffer manager registers

The Spatial Decoder buffer manager is intended to be configured once immediately after the device is reset. In normal operation, there is no requirement to reconfigure the buffer manager.

After reset is removed from the Spatial Decoder, the buffer manager is halted (with its access register, `buffer_manager_access`, set to 1) awaiting configuration. After the registers have been configured, `buffer_manager_access` can be set to 0 and decoding can commence.

Most of the registers used in the buffer manager cannot be accessed reliably while the buffer manager is operating. Before any of the buffer manager registers are accessed  
30 buffer\_manager\_access must be set to 1. This makes it essential to observe the protocol of waiting until the value 1 can be read from buffer\_manager\_access. The time taken to obtain and release access should be taken into

consideration when polling such registers as `cdb_full` and `cdb_empty` to monitor buffer conditions.

Register name	Size/Dir	Reset State	Description
<code>buffer_manager_access</code>	1 rw	1	This access bit stops the operation of the buffer manager so that its various registers can be accessed reliably. See A 6.4.1.  Note: this access register is unusual as its default state after reset is 1, i.e. after reset the buffer manager is halted awaiting configuration via the microprocessor interface.
<code>buffer_manager_keyhole_address</code>	6 rw	x	Keyhole access to the extended address space used for the buffer manager registers shown below. See A 6.4.3 for more information about accessing registers through a keyhole.
<code>buffer_manager_keyhole_data</code>	8 rw	x	
<code>buffer_limit</code>	18 rw	x	This specifies the overall size of the DRAM array attached to the Spatial Decoder. All buffer addresses are provided modulo this buffer size and so will wrap round within the DRAM provided.
<code>cdb_base</code>	18 rw	x	These registers point to the base of the coded data (cdb) and Token (tb) buffers.
<code>tb_base</code>			
<code>cdb_length</code>	18 rw	x	These registers specify the length (i.e. size) of the coded data (cdb) and Token (tb) buffers.
<code>tb_length</code>			
<code>cdb_read</code>	18 ro	x	These registers hold an offset from the buffer base and indicate where data will be read from next.
<code>tb_read</code>			
<code>cdb_number</code>	18 ro	x	These registers show how much data is currently held in the buffers.
<code>tb_number</code>			
<code>cdb_full</code>	1 ro	x	These registers will be set to 1 if the coded data (cdb) or Token (tb) buffers are full.
<code>tb_full</code>			
<code>cdb_empty</code>	1 ro	x	These registers will be set to 1 if the coded data (cdb) or Token (tb) buffers are empty.
<code>tb_empty</code>			

Table A.13.1 Buffer manager registers (contd)

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### A.13.1.1 Buffer manager pointer values

Typically, data is transferred between the Spatial Decoder and the off\_chip DRAM in 64 byte bursts (using the DRAM's fast page mode). All the buffer pointers and length registers refer to these 64 byte (512 bit) blocks of data. So, the buffer manager's 18 bit registers describe a 256 k block linear address space (i.e., 128 Mb).

The 64 byte transfer is independent of the width (8, 16 or 32 bits) of the DRAM interface.

### 10 A.13.2 Use of the buffer manager registers

The Spatial Decoder buffer manager has two sets of registers that define two similar buffers. The buffer limit register (buffer\_limit) defines the physical upper limit of the memory space. All addresses are calculated modulo this number.

Within the limits of the available memory, the extent of each buffer is defined by two registers: the buffer base (cdb\_base and tb\_base) and the buffer length (cdb\_length and tb\_length). All the registers described thus far must be configured before the buffers can be used.

The current status of each buffer is visible in 4 registers. The buffer read register (cdb\_read and tb\_read) indicates an offset from the buffer base from which data will be read next. The buffer number registers (cdb\_number and tb\_number) indicate the amount of data currently held by buffers. The status bits cdb\_full, tb\_full, cdb\_empty and tb\_empty indicate if the buffers are full or empty.

As stated in A.13.1.1, the unit for all the above mentioned registers is a 512 bit block of data. Accordingly, the value read from cdb\_number should be multiplied by 512 to obtain the number of bits in the coded data buffer.

### A.13.3 Zero buffers

Still picture applications (e.g., using JPEG) that do

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not have a "real-time" requirement will not need the large off-chip buffers supported by the buffer manager. In this case, the DRAM interface can be configured (by writing 1 to the zero\_buffers register) to ignore the buffer manager to  
 5 provide a 128 bit stream on-chip FIFO for the coded data buffer and the Token buffers.

The zero buffers option may also be appropriate for applications which operate working at low data rates and with small picture formats.

10 Note: the zero\_buffers register is part of the DRAM interface and, therefore, should be set only during the post-reset configuration of the DRAM interface.

#### A.13.4 Buffer operation

The data transfer through the buffers is controlled by a  
 15 handshake Protocol. Hence, it is guaranteed that no data errors will occur if the buffer fills or empties. If a buffer is filled, then the circuits trying to send data to the buffer will be halted until there is space in the buffer. If a buffer continues to be full, more processing  
 20 stages "up steam" of the buffer will halt until the Spatial Decoder is unable to accept data on its input port. Similarly, if a buffer empties, then the circuits trying to remove data from the buffer will halt until data is available.

25 As described in A.13.2, the position and size of the coded data and Token buffer are specified by the buffer base and length registers. The user is responsible for configuring these registers and for ensuring that there is no conflict in memory usage between the two buffers.

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## SECTION A.14 Video Demux

The Video Demux or Video parser as it is also called, completes the task of converting coded data into Tokens started by the Start Code Detector. There are four main processing blocks in the Video Demux: Parser State Machine, Huffman decoder (including an ITOD), Macroblock counter and ALU.

The Parser or state machine follows the syntax of the coded video data and instructs the other units. The Huffman decoder converts variable length coded (VLC) data into integers. The Macroblock counter keeps track of which section of a picture is being decoded. The ALU performs the necessary arithmetic calculations.

### A.14.1 Video Demux registers

Register name	Size/Dir.	Reset State	Description
demux_access <i>CED_H_CTRL[7]</i>	1 rw	0	This access bit stops the operation of the Video Demux so that its various registers can be accessed reliably. See A.6.4.1
huffman_error_code <i>CED_H_CTRL[6,4]</i>	3 ro		When the Video Demux stops following the generation of a huffman_event interrupt request this 3 bit register holds a value indicating why the interrupt was generated. See A.14.5.1
parser_error_code <i>CED_H_MUX_ERR</i>	8 ro		When the Video Demux stops following the generation of a parser_event interrupt request this 8 bit register holds a value indicating why the interrupt was generated. See A.14.5.2
demux_keyhole_address <i>CED_H_KEYHOLE_ADDR</i>	12 rw	x	Keyhole access to the Video Demux's extended address space. See A.6.4.3 for more information about accessing registers through a keyhole.
demux_keyhole_data <i>CED_H_KEYHOLE</i>	8 rw	x	

Table A.14.1 Top level Video Demux registers

Register name	Size/Dir	Reset State	Description
dummy_last_picture CED_H_ALU_REG0 r_rom_control r_dummy_last_frame_bit	1 rw	0	<p>When this register is set to 1 the Video Demux will generate information for a "dummy" Intra picture as the last picture of an MPEG sequence.</p> <p>This function is useful when the Temporal Decoder is configured for automatic picture re-ordering (see A.18.3.5, "Picture sequence re-ordering", to flush the last P or I picture out of the Temporal Decoder.</p> <p>No "dummy" picture is required if:</p> <ul style="list-style-type: none"> <li>• the Temporal Decoder is not configured for re-ordering</li> <li>• another MPEG sequence will be decoded immediately (as this will also flush out the last picture)</li> <li>• the coding standard is not MPEG</li> </ul>
field_info CED_H_ALU_REG0 r_rom_control r_field_info_bit	1 rw	0	<p>When this register is set to 1 the first byte of any MPEG extra_information_picture is placed in the FIELD_INFO Token. See A.14.7.1</p>
continue CED_H_ALU_REG0 r_rom_control r_continue_bit	1 rw	0	<p>This register allows user software to control how much extra, user or extension data it wants to receive when it is detected by the decoder.</p> <p>See A.14.6 and A.14.7</p>
rom_revision CED_H_ALU_REG1 r_rom_revision	8 ro		<p>Immediately following reset this holds a copy of the microcode ROM revision number.</p> <p>This register is also used to present to control software data values read from the coded data. See A.14.6, "Receiving User and Extension data", and A.14.7, "Receiving Extra Information",</p>

Table A.14.1 Top level Video Demux registers (contd)

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Register name	Size/Dir	Reset State	Description
huffman_event	1 rw	0	A Huffman event is generated if an error is found in the coded data. See A.14.5.1 for a description of these events.
huffman_mask	1 rw	0	
parser_event	1 rw	0	A Parser event can be in response to errors in the coded data or to the arrival of information at the Video Demux that requires software intervention. See A.14.5.2 for a description of these events.
parser_mask	1 rw	0	

Table A.14.1 Top level Video Demux registers (contd)

Register name	Size/Dir	Reset State	Description
component_name_0	8 rw	x	During JPEG operation the register component_name_n holds an 8 bit value indicating (to an application) which colour component has the component ID n.
component_name_1			
component_name_2			
component_name_3			
horiz_pels	16 rw	x	These registers hold the horizontal and vertical dimensions of the video being decoded in pixels.
vert_pels	16 rw		
horiz_macroblocks	16 rw	x	These registers hold the horizontal and vertical dimensions of the video being decoded in macroblocks.
vert_macroblocks	16 rw		

Table A.14.2 video demux picture construction registers

Register name	Size/Dir.	Reset State	Description
max_n	2 rw	x	These registers hold the macroblock width and height in blocks (8 x 8 pixels). The values 0 to 3 indicate a width/height of 1 to 4 blocks.  See section A.14.2
max_v	2 rw	x	
max_component_id	2 rw	x	The values 0 to 3 indicate that 1 to 4 different video components are currently being decoded.  See section A.14.2
Nf	8 rw	x	During JPEG operation this register holds the parameter Nf (number of image components in frame).
blocks_h_0 blocks_h_1 blocks_h_2 blocks_h_3	2 rw	x	For each of the 4 colour components the registers blocks_h_n and blocks_v_n hold the number of blocks horizontally and vertically in a macroblock for the colour component with component ID n.  See section A.14.2
blocks_v_0 blocks_v_1 blocks_v_2 blocks_v_3	2 rw	x	
iq_0 iq_1 iq_2 iq_3	2 rw	x	The two bit value held by the register iq_n describes which Inverse Quantisation table is to be used when decoding data with component ID n

Table A.14.2 Video demux picture  
construction registers (contd)

**A.14.1-1 - Register loading and Token generation**

Many of the registers in the Video Demux hold values that relate directly to parameters normally communicated in the coded picture/video data. For example, the horiz\_pels register corresponds to the MPEG sequence header information, horizontal\_size, and the JPEG frame header parameter, X. These registers are loaded by the Video Demux when the appropriate coded data is decoded. These registers are also associated with a Token. For example, the register, horiz\_pels, is associated with Token, HORIZONTAL\_SIZE. The Token is generated by the Video Demux when (or soon after) the coded data is decoded. The Token can also be supplied directly to the input of the Spatial Decoder. In this case, the value carried by the Token will configure the Video Demux register associated with it.

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Register Name	Size/Dir.	Reset State	Description
dc_huff_0	2		The two bit value held by the register dc_huff_n describes which Huffman decoding table is to be used when decoding the DC coefficients of data with component ID n.
dc_huff_1	rw		
dc_huff_2			
dc_huff_3			
ac_huff_0	2		Similarly ac_huff_n describes the table to be used when decoding AC coefficients.
ac_huff_1	rw		
ac_huff_2			
ac_huff_3			
dc_bits_0[15:0]	8		Each of these is a table of 16, eight bit values. They provide the BITS information (see JPEG Huffman table specification) which form part of the description of two DC and two AC Huffman tables.
dc_bits_1[15:0]	rw		
ac_bits_0[15:0]	8		
ac_bits_1[15:0]	rw		
dc_huffval_0[11:0]	8		Each of these is a table of 12, eight bit values. They provide the HUFFVAL information (see JPEG Huffman table specification) which form part of the description of two DC Huffman tables.
dc_huffval_1[11:0]	rw		
ac_huffval_0[161:0]	8		Each of these is a table of 162, eight bit values. They provide the HUFFVAL information (see JPEG Huffman table specification) which form part of the description of two AC Huffman tables.
ac_huffval_1[161:0]	rw		
dc_zssss_0	8		These 8 bit registers hold values that are "special cases" to accelerate the decoding of certain frequently used JPEG VLCs.
dc_zssss_1	rw		
ac_eob_0	8		
ac_eob_1	rw		
ac_zrl_0	8		ac_zrl - run of 16 zeros
ac_zrl_1	rw		

Table A.14.3 Video demux Huffman table registers

00000000000000000000000000000000

Register name	Size/Dir.	Reset State	Description
buffer_size	10 rw		<p>This register is loaded when decoding MPEG data with a value indicating the size of VBV buffer required in an ideal decoder.</p> <p>This value is not used by the decoder chips. However, the value it holds may be useful to user software when configuring the coded data buffer size and to determine whether the decoder is capable of decoding a particular MPEG data file.</p>
pel_aspect	4 rw		<p>This register is loaded when decoding MPEG data with a value indicating the pel aspect ratio. The value is a 4 bit integer that is used as an index into a table defined by MPEG.</p> <p>See the MPEG standard for a definition of this table.</p> <p>This value is not used by the decoder chips. However, the value it holds may be useful to user software when configuring a display or output device.</p>
bit_rate	18 rw		<p>This register is loaded when decoding MPEG data with a value indicating the coded data rate.</p> <p>See the MPEG standard for a definition of this value.</p> <p>This value is not used by the decoder chips. However, the value it holds may be useful to user software when configuring the decoder start-up registers.</p>
pic_rate	4 rw		<p>This register is loaded when decoding MPEG data with a value indicating the picture rate.</p> <p>See the MPEG standard for a definition of this value.</p> <p>This value is not used by the decoder chips. However, the value it holds may be useful to user software when configuring a display or output device.</p>
constrained	1 rw		<p>This register is loaded when decoding MPEG data to indicate if the coded data meets MPEG's constrained parameters.</p> <p>See the MPEG standard for a definition of this flag.</p> <p>This value is not used by the decoder chips. However, the value it holds may be useful to user software to determine whether the decoder is capable of decoding a particular MPEG data file.</p>

Table A.14.4 Other Video Demux registers

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Register name	Size/Dtr.	Reset State	Description																
picture_type	2 rw		During MPEG operation this register holds the picture type of the picture being decoded .																
h_251_pic_type	8 rw		<p>This register is loaded when decoding H.251 data. It holds information about the picture format.</p> <table><tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr><tr><td>r</td><td>r</td><td>s</td><td>d</td><td>f</td><td>q</td><td>r</td><td>r</td></tr></table> <p>Flags:</p> <p>s - Split Screen Indicator</p> <p>d - Document Camera</p> <p>f - Freeze Picture Release</p> <p>This value is not used by the decoder chips. However, the information should be used when configuring horiz_pels, vert_pels and the display or output device.</p>	7	6	5	4	3	2	1	0	r	r	s	d	f	q	r	r
7	6	5	4	3	2	1	0												
r	r	s	d	f	q	r	r												
broken_closed	2 rw		<p>During MPEG operation this register holds the broken_link and closed_gop information for the group of pictures being decoded.</p> <table><tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr><tr><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>c</td><td>b</td></tr></table> <p>Flags:</p> <p>c - closed_gop</p>	7	6	5	4	3	2	1	0	r	r	r	r	r	r	c	b
7	6	5	4	3	2	1	0												
r	r	r	r	r	r	c	b												

Table A.14.4 Other Video Demux registers (contd)



Table A.14.4 Other Video Demux registers (contd)

Register name	Size/Dir.	Reset State	Description
restart_interval	8 rw		This register is loaded when decoding JPEG data with a value indicating the minimum start-up delay before decoding should start.  See the MPEG standard for a definition of this value.

Table A.14.4 Other Video Demux registers (contd)

register	Token	standard	comment
component_name_n	COMPONENT_NAME	JPEG	in coded data.
		MPEG	not used in standard.
		H.261	
horiz_pels	HORIZONTAL_SIZE	MPEG	in coded data.
vert_pels	VERTICAL_SIZE	JPEG	
		H.261	automatically derived from picture type.
horiz_macroblocks	HORIZONTAL_MBS	MPEG	control software must derive from
vert_macroblocks	VERTICAL_MBS	JPEG	horizontal and vertical picture size.
		H.261	automatically derived from picture type.
max_h	DEFINE_MAX_SAMPLING	MPEG	control software must configure.  Sampling structure is fixed by standard.
max_v		JPEG	in coded data.
		H.261	automatically configured for 4:2:0 video.

Table A.14.5 Register to Token cross reference

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Table A.14.5 Register to Token cross  
reference (contd)

Table A.14.5 Register to Token cross reference (contd)

register	Token	standard	comment
broken_closed	BROKEN_CLOSED	MPEG	in coded data.
		JPEG	not used in standard
		H.261	
prediction_mode	PREDICTION_MODE	MPEG	in coded data.
		JPEG	not used in standard
		H.261	
h_261_pic_type	PICTURE_TYPE (when standard is H.261)	MPEG	not relevant
		JPEG	
		H.261	in coded data.
vbv_delay	VBV_DELAY	MPEG	in coded data.
		JPEG	not used in standard
		H.261	
pic_number	Carried by:	MPEG	Generated by start code detector.
	PICTURE_START	JPEG	
		H.261	
coding_standard	CODING_STANDARD	MPEG	configured in start code by control
		JPEG	software detector.
		H.261	

**Table A.14.5 Register to Token  
cross reference (contd)**

#### **A.14.2 Picture structure**

In the present invention, picture dimensions are described to the Spatial Decoder in 2 different units:

5 pixels and macroblocks. JPEG and MPEG both communicate picture dimensions in pixels. Communicating the dimensions in pixels determine the area of the buffer that contains the valid data; this may be smaller than the total buffer

10 size. Communicating dimensions in macroblocks determines the size of buffer required by the decoder. The macroblock dimensions must be derived by the user from the pixel

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dimensions. The Spatial Decoder registers associated with this information are: `horiz_pels`, `vert_pels`, `horiz_macroblocks` and `vert_macroblocks`.

The Spatial Decoder registers, `blocks_h_n`, `blocks_v_n`, `max_h`, `max_v` and `max_component_id` specify the composition of the macroblocks (minimum coding units in JPEG). Each is a 2 bit register that can hold values in the range 0 to 3. All except `max_component_id` specify a block count of 1 to 4. For example, if register `max_h` holds 1, then a  
 10 macroblock is two blocks wide. Similarly, `max_component_id` specifies the number of different color components involved.

	2:1:1	4:2:2	4:2:0	1:1:1
<code>max_h</code>	1	1	1	0
<code>max_v</code>	0	1	1	0
<code>max_component_id</code>	2	2	2	2
<code>blocks_h_0</code>	1	1	1	0
<code>blocks_h_1</code>	0	0	0	0
<code>blocks_h_2</code>	0	0	0	0
<code>blocks_h_3</code>	x	x	x	x
<code>blocks_v_0</code>	0	1	1	0
<code>blocks_v_1</code>	0	1	0	0
<code>blocks_v_2</code>	0	1	0	0
<code>blocks_v_3</code>	x	x	x	x

Table A.14.6 Configuration for various macroblock formats



DATA and DHT\_MARKER Tokens to the input of the Spatial Decoder while the Spatial Decoder is configured for JPEG operation. This mechanism can be used for configuring the DC coefficient Huffman tables required for MPEG operation, however, the coding standard of the Spatial Decoder must be set to JPEG while the tables are down loaded.

E	7	6	5	4	3	2	1	0	Token Name
1	0	0	0	1	0	1	0	1	CODING_STANDARD
0	0	0	0	0	0	0	0	1	1 = JPEG
0	0	0	0	1	1	1	0	0	DHT_MARKER
1	0	0	0	0	0	1	x	x	DATA
1	t	t	t	t	t	t	t	t	T <sub>n</sub> - Value indicating which Huffman table is to be loaded. JPEG allows 4 tables to be downloaded.  Values 0x00 and 0x01 specify DC coefficient coding tables 0 and 1  Values 0x10 and 0x11 specifies AC coefficient coding tables 0 and 1.
1	n	n	n	n	n	n	n	n	
1	n	n	n	n	n	n	n	n	
1	n	n	n	n	n	n	n	n	
e	n	n	n	n	n	n	n	n	V <sub>ij</sub> - Words carrying HUFFVAL information (the number of words depends on the number of different symbols).  e - the extension bit will be 0 if this is the end of the DATA Token or 1 if another table description is contained in the same DATA Token.

This sequence can be repeated to allow several tables to be described in a single token

Table A.14.7 Huffman table configuration via Tokens



#### **A.14.3-1.4 Configuration by MPI**

The AC and DC coefficient Huffman tables can also be written directly to registers via the MPI. See Table A.14.3.

- 5     · The registers `dc_bits_0[15:0]` and `dc_bits_1[15:0]` hold the BITS values for tables 0x00 and 0x01.
- The registers `ac_bits_0[15:0]` and `ac_bits_1[15:0]` hold the BITS values for tables 0x10 and 0x11.
- The registers `dc_huffval_0[11:0]` and
- 10    `dc_huffval_1[11:0]` hold the HUFFVAL values for tables 0x00 and 0x01.
- The registers `ac_huffval_0[161:0]` and `ac_huffval_1[161:0]` hold the HUFFVAL values for tables 0x10 and 0x11.

#### **A.14.4 Configuring for different standards**

The Video Demux supports the requirements of MPEG, JPEG and H.261. The coding standard is configured automatically by the CODING\_STANDARD Token generated by the Start Code Detector.

##### **A.14.4.1 H.261 Huffman tables**

All the Huffman tables required to decode H.261 are held in ROMs within the Spatial Decoder and more particular in the parser state machine of the Video demux and, therefore require no user intervention.

##### **A.14.4.2 H.261 Picture structure**

- H.261 is defined as supporting only two picture formats: CIF and QCIF. The picture format in use is signalled in the PTYPE section of the bitstream. When this data is decoded by the Spatial Decoder, it is placed in the
- 30    `h_261_pic_type` registers and the PICTURE\_TYPE Token. In addition, all the picture and macroblock construction registers are configured automatically.

The information in the various registers is also placed into their related Tokens (see Table A.14.5),

and this ensures that other decoder chips (such as the Temporal Decoder) are correctly configured.

#### A.14.4.3 MPEG Huffman tables

The majority of the Huffman coding tables required to decode MPEG are held in ROMs within the Spatial Decoder (again, in the parser state machine) and, thus, require no user intervention. The exceptions are the tables required for decoding the DC coefficients of Intral macroblocks. Two tables are required, one for chroma the other for luma. These must be configured by user software before decoding begins.

macroblock construction	CIF / QCIF	picture construction	CIF	QCIF
max_h	1	horiz_pels	352	176
max_v	1	vert_pels	288	144
max_component_id	2	horiz_macroblocks	22	11
blocks_h_0	1	vert_macroblocks	18	9
blocks_h_1	0			
blocks_h_2	0			
blocks_v_0	1			
blocks_v_1	0			
blocks_v_2	0			

**Table A.14.8 Automatic settings for H.261**

Table A.14.10 shows the sequence of Tokens required to configure the DC coefficient Huffman tables within the Spatial Decoder. Alternatively, the same results can be obtained by writing this information to registers via the MPI.

The registers dc\_huff\_n control which DC coefficient Huffman tables are used with each color component. Table

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A.14.9 shows how they should be configured for MPEG operation. This can be done directly via the MPI or by using the MPEG\_DCH\_TABLE Token.

dc_huff_0	0
dc_huff_1	1
dc_huff_2	1
dc_huff_3	x

Table A.14.9 MPEG DC Huffman table selection via MPI

E	[7:0]	Token Name
1	0x15	CODING_STANDARD
0	0x01	1 = JPEG
0	0x1C	DHT_MARKER
1	0x04	DATA (could be any colour component, 0 is used in this example)
1	0x00	0 indicates that this Huffman table is DC coefficient coding table 0

Table A.14.10 MPEG DC Huffman table configuration

E	[7:0]	Token Name
1	0x00	16 words carrying BITS information describing a total of 9 different VLCs:
1	0x02	
1	0x03	
1	0x01	
1	0x01	
1	0x01	
1	0x01	
1	0x00	
1	0x00	
1	0x00	If configuring via the MPI rather than with Tokens these values would be written into the dc_bits_0[15:0] registers.
1	0x00	
1	0x00	
1	0x00	
1	0x00	
1	0x01	9 words carrying HUFFVAL information
1	0x02	
1	0x00	
1	0x03	
1	0x04	
1	0x05	
1	0x06	
1	0x07	
0	0x08	

Table A.14.10 MPEG DC Huffman  
table configuration (contd)

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E		[7:0]	Token Name
0	0x1C		DHT_MARKER
1	0x04		DATA (could be any colour component, 0 is used in this example)
1	0x01		1 indicates that this Huffman table is DC coefficient coding table 1
1	0x00		16 words carrying BITS information describing a total of 9
1	0x03		different VLCs:
1	0x01		3, 2 bit codes
1	0x01		1, 3 bit codes
1	0x01		1, 4 bit codes
1	0x01		1, 5 bit codes
1	0x01		1, 6 bit codes
1	0x00		1, 7 bit codes
1	0x00		1, 8 bit codes
1	0x00		If configuring via the MPI rather than with Tokens these values would be
1	0x00		written into the dc_bits_1[15:0] registers.
1	0x00		
1	0x00		
1	0x00		
1	0x00		9 words carrying HUFFVAL information
1	0x01		If configuring via the MPI rather than with Tokens these values would be
1	0x02		written into the dc_huffval_1[11:0] registers.
1	0x03		
1	0x04		
1	0x05		
1	0x06		
1	0x07		
0	0x08		
1	0x04		MPEG_DCH_TABLE
0	0x00		Configure so table 0 is used for component 0
1	0x05		MPEG_DCH_TABLE
0	0x01		Configure so table 1 is used for component 1
1	0x06		MPEG_DCH_TABLE
0	0x01		Configure so table 1 is used for component 2

Table A.14.10 MPEG DC Huffman table configuration (contd)

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E	[7:0]	Token Name
1	0x15	CODING_STANDARD
0	0x02	2 = JPEG

Table A.14.10 MPEG DC Huffman  
table configuration (contd)

#### A.14.4.4 MPEG Picture structure

The macroblock construction defined for MPEG is the same as that used by H.261. The picture dimensions are encoded in the coded data.

For standard 4:2:0 operation, the macroblock characteristics should be configured as indicated in Table A.14.8. This can be done either by writing to the registers as indicated or by applying the equivalent Tokens (see Table A.14.5) to the input of the Spatial Decoder.

The approach taken to configure picture dimensions will depend upon the application. If the picture format is known before decoding starts, then the picture construction registers listed in Table A.14.8 can be initialized with appropriate values. Alternatively, the picture dimensions can be decoded from the coded data and used to configure the Spatial Decoder. In this case the user must service the parser error ERR\_MPEG\_SEQUENCE, see A.14.8, "Changes at the MPEG sequence layer".

**A.14.4.5- JPEG**

Within baseline JPEG, there are a number of encoder options that significantly alter the complexity of the control software required to operate the decoder. In general, the Spatial Decoder has been designed so that the required support is minimal where the following condition is met:

Number of color components per frame is less than 5 ( $N_c \leq 4$ )

10 **A.14.4.6 JPEG Huffman tables**

Furthermore, JPEG allows Huffman coding tables to be down loaded to the decoder. These tables are used when decoding the VLCs describing the coefficients. Two tables are permitted per scan for decoding DC coefficients and two for the AC coefficients.

15 There are three different types of JPEG file: Interchange format, an abbreviated format for compressed image data, and an abbreviated format for table data. In an interchange format file there is both compressed image data and a definition of all the tables (Huffman, Quantization etc.) required to decode the image data. The abbreviated image data format file omits the table definitions. The abbreviated table format file only contains the table definitions.

25 The Spatial Decoder will accept all three formats. However, abbreviated image data files can only be decoded if all the required tables have been defined. This definition can be done via either of the other two JPEG file types, or alternatively, the tables could be set-up by user software.

30 If each scan uses a different set of Huffman tables, then the table definitions are placed (by the encoder) in the coded data before each scan. These are automatically loaded by the Spatial Decoder for use during this and any

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subsequent scans.

To improve the performance of the Huffman decoding, certain commonly used symbols are specially cased. These are: DC coefficient with magnitude 0, end of block AC  
 5 coefficients and run of 16 zero AC coefficients. The values for these special cases should be written into the appropriate registers.

#### **A.14.4.6.1 Table selection**

The registers dc\_huff\_n and ac\_huff\_n control which AC  
 10 and DC coefficient Huffman tables are used with which color component. During JPEG operation, these relationships are defined by the TD<sub>j</sub> and Ta<sub>j</sub> fields of the scan header syntax.

#### **A.14.4.7 JPEG Picture structure**

There are two distinct levels of baseline JPEG decoding  
 15 supported by the Spatial Decoder: up to 4 components per frame ( $N_f \leq 4$ ) and greater than 4 components per frame ( $N_f > 4$ ). If  $N_f > 4$  is used, the control software required becomes more complex.

##### **A.14.4.7.1 $N_f \leq 4$**

The frame component specification parameters contained  
 20 in the JPEG frame header configure the macroblock construction registers (see Table A.14.8) when they are decoded. No user intervention is required, as all the specifications required to decode the 4 different color  
 25 components as defined.

For further details of the options provided by JPEG the reader should study the JPEG specification. Also, there is a short description of JPEG picture formats in § A.16.1.

##### **A.14.4.7.2 JPEG with more than 4 components**

30 The Spatial Decoder can decode JPEG files containing up to 256 different color components (the maximum permitted by JPEG). However, additional user intervention is required if more than 4 color component are to be decoded. JPEG only allows a maximum of 4 components in any scan.

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only allows a maximum of 4 components in any scan.

#### **A.14.4.8 Non-standard variants**

As stated above, the Spatial Decoder supports some picture formats beyond those defined by JPEG and MPEG.

5     JPEG limits minimum coding units so that they contain no more than 10 blocks per scan. This limit does not apply to the Spatial Decoder since it can process any minimum coding unit that can be described by blocks\_h\_n, blocks\_v\_n, max\_h and max\_v.

10     MPEG is only defined for 4:2:0 macroblocks (see Table A.14.8). However, the Spatial Decoder can process three other component macroblock structures, (e.g., 4:2:2).

#### **A.14.5 Video events and errors**

15     The Video Demux can generate two types of events: parser events and Huffman events. See A.6.3, "Interrupts", for a description of how to handle events and interrupts.

##### **A.14.5.1 Huffman events**

20     Huffman events are generated by the Huffman decoder. The event which is indicated in huffman\_event and huffman\_mask determines whether an interrupt is generated. If huffman\_mask is set to 1, an interrupt will be generated and the Huffman decoder will halt. The register huffman\_error\_code[2:0] will hold a value indicating the cause of the event.

25     If 1 is written to huffman\_event after servicing the interrupt, the Huffman decoder will attempt to recover from the error. Also, if huffman\_mask was set to 0 (masking the interrupt and not halting the Huffman decoder) the Huffman decoder will attempt to recover from the error automatically.

30

##### **A.14.5.2 Parser events**

Parser events are generated by the Parser. The event is

00000000 00000000 00000000 00000000

indicated in parser\_event. Thereafter, parser\_mask determines whether an interrupt is generated. If parser\_mask is set to 1, an interrupt will be generated and the Parser will halt. The register parser\_error\_code[7:0] will hold a value indicating the cause of event.

If 1 is written to huffman\_event after servicing the interrupt, the Huffman decoder will attempt to recover from the error. Also, if huffman\_mask was set to 0 (masking the interrupt and not halting the Huffman decoder) the Huffman decoder will attempt to recover from the error automatically.

If 1 is written to parser\_event after servicing the interrupt, the Parser will start operation again. If the event indicated a bitstream error, the Video Demux will attempt to recover from the error.

If parser\_mask was set to 0, the Parser will set its event bit, but will not generate an interrupt or halt. It will continue operation and attempt to recover from the error automatically.

00000000 00000000 00000000 00000000

huffman_error_code			Description
[2]	[1]	[0]	
0	0	0	No error. This error should not occur during normal operation.
X	0	1	Failed to find terminal code in VLC within 16 bits.
X	1	0	Found serial data when Token expected
X	1	1	Found Token when serial data expected
1	X	X	Information describing more than 64 coefficients for a single block was decoded indicating a bitstream error. The block output by the Video Demux will contain only 64 coefficients.

Table A.14.11 Huffman error codes

parser_error_code[7:0]	Description
0x00	ERR_NO_ERROR No Parser error has occurred, this event should not occur during normal operation
0x10	ERR_EXTENSION_TOKEN An EXTENSION_DATA Token has been detected by the Parser. The detection of this Token should precede a DATA Token that contains the extension data. See A.14.6
0x11	ERR_EXTENSION_DATA Following the detection of an EXTENSION_DATA Token, a DATA Token containing the extension data has been detected. See A.14.6
0x12	ERR_USER_TOKEN A USER_DATA Token has been detected by the Parser. The detection of this Token should precede a DATA Token that contains the user data. See A.14.6
0x13	ERR_USER_DATA Following the detection of a USER_DATA Token, a DATA Token containing the user data has been detected. See A.14.6
0x20	ERR_PSPARE H.261 PSARE information has been detected see A.14.7

Table A.14.12 Parser error codes (Sheet 1 of 5)

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

parser_error_code[3:0]	Description
0x21	ERR_GSPARE H.261 GSPARE information has been detected see A.14.7
0x22	ERR_PTYPE The value of the H.261 picture type has changed. The register h_261_pic_type can be inspected to see what the new value is.
0x30	ERR_JPEG_FRAME
0x31	ERR_JPEG_FRAME_LAST
0x32	ERR_JPEG_SCAN Picture size or Ns changed
0x33	ERR_JPEG_SCAN_COMP Component Change !
0x34	ERR_ONL_MARKER
0x40	ERR_MPEG_SEQUENCE One of the parameters communicated in the MPEG sequence layer has changed. See A.14.8
0x41	ERR_EXTRA_PICTURE MPEG extra_information_picture has been detected see A.14.7
0x42	ERR_EXTRA_SLICE MPEG extra_information_slice has been detected see A.14.7
0x43	ERR_VBV_DELAY The VBV_DELAY parameter for the first picture in a new MPEG video sequence has been detected by the Video Demux. The new value of delay is available in the register vbv_delay.  The first picture of a new sequence is defined as the first picture after a sequence end. FLUSH or reset.
0x80	ERR_SHORT_TOKEN An incorrectly formed Token has been detected. This error should not occur during normal operation.

Table A.14.12 Parser error codes (Sheet 2 of 5)

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parser_error_code(7:0)	Description
0x90	<p>ERR_H261_PIC_END_UNEXPECTED</p> <p>During H.261 operation the end of a picture has been encountered at an unexpected position. This is likely to indicate an error in the coded data.</p>
0x91	<p>ERR_GN_BACKUP</p> <p>During H.261 operation a group of blocks has been encountered with a group number less than that expected. This is likely to indicate an error in the coded data.</p>
0x92	<p>ERR_GN_SKIP_GOB</p> <p>During H.261 operation a group of blocks has been encountered with a group number greater than that expected. This is likely to indicate an error in the coded data.</p>
0xA0	<p>ERR_NBASE_TAB</p> <p>During JPEG operation there has been an attempt to down load a Huffman table that is not supported by baseline JPEG (baseline JPEG only supports tables 0 and 1 for entropy coding).</p>
0xA1	<p>ERR_QUANT_PRECISION</p> <p>During JPEG operation there has been an attempt to down load a quantisation table that is not supported by baseline JPEG (baseline JPEG only supports 8 bit precision in quantisation tables).</p>
0xA2	<p>ERR_SAMPLE_PRECISION</p> <p>During JPEG operation there has been an attempt to specify a sample precision greater than that supported by baseline JPEG (baseline JPEG only supports 8 bit precision).</p>
0xA3	<p>ERR_NBASE_SCAN</p> <p>One or more of the JPEG scan header parameters Ss, Se, Ah and Al is set to a value not supported by baseline JPEG (indicating spectral selection and/or successive approximation which are not supported in baseline JPEG).</p>
0xA4	<p>ERR_UNEXPECTED_DNL</p> <p>During JPEG operation a DNL marker has been encountered in a scan that is not the first scan in a frame.</p>
0xA5	<p>ERR_EOS_UNEXPECTED</p> <p>During JPEG operation an EOS marker has been encountered in an unexpected place.</p>

Table A.14.12 Parser error codes (Sheet 3 of 5)

parser_error_code(7:0)	Description
0xA6	ERR_RESTART_SKIP During JPEG operation a restart marker has been encountered either in an unexpected place or the value of the restart marker is unexpected. If a restart marker is not found when one is expected the Huffman event "Found serial data when token expected" will be generated.
0xB0	ERR_SKIP_INTRA During MPEG operation, a macro block with a macro block address increment greater than 1 has been found within an intra (I) picture. This is illegal and probably indicates a bitstream error.
0xB1	ERR_SKIP_DINTRA During MPEG operation, a macro block with a macro block address increment greater than 1 has been found within an DC only (D) picture. This is illegal and probably indicates a bitstream error.
0xB2	ERR_BAD_MARKER During MPEG operation, a marker bit did not have the expected value. This probably indicates a bitstream error.
0xB3	ERR_O_MBTYPE During MPEG operation, within a DC only (D) picture, a macroblock was found with a macroblock type other than 1. This is illegal and probably indicates a bitstream error.
0xB4	ERR_O_MBEND During MPEG operation, within a DC only (D) picture, a macroblock was found with 0 in its end of macroblock bit. This is illegal and probably indicates a bitstream error.
0xB5	ERR_SVP_BACKUP During MPEG operation, a slice has been encountered with a slice vertical position less than that expected. This is likely to indicate an error in the coded data.
0xB6	ERR_SVP_SKIP_ROWS During MPEG operation, a slice has been encountered with a slice vertical position greater than that expected. This is likely to indicate an error in the coded data.
0xB7	ERR_FST_MBA_BACKUP During MPEG operation, a macroblock has been encountered with a macro block address less than that expected. This is likely to indicate an error in the coded data.

Table A.14.12 Parser error codes (Sheet 4 of 5)

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Each standard uses a different sub-set of the defined Parser error codes.

5

Table A.14.13 Parser error codes and the different standards

Token Name	MPEG	JPEG	H.261
ERR_JPEG_SCAN_COMP		✓	
ERR_DNL_MARKER		✓	
ERR_MPEG_SEQUENCE	✓		
ERR_EXTRA_PICTURE	✓		
ERR_EXTRA_SLICE	✓		
ERR_VBV_DELAY	✓		
ERR_SHORT_TOKEN	✓	✓	✓
ERR_H261_PIC_END_UNEXPECTED			✓
ERR_GN_BACKUP			✓
ERR_GN_SKIP_GOB			✓
ERR_NBASE_TAB		✓	
ERR_QUANT_PRECISION		✓	
ERR_SAMPLE_PRECISION		✓	
ERR_NBASE_SCAN		✓	
ERR_UNEXPECTED_DNL		✓	
ERR_EOS_UNEXPECTED		✓	
ERR_RESTART_SKIP		✓	
ERR_SKIP_INTRA	✓		
ERR_SKIP_DINTRA	✓		
ERR_BAD_MARKER	✓		
ERR_D_MBTYPE	✓		
ERR_D_MBEND	✓		
ERR_SVP_BACKUP	✓		
ERR_SVP_SKIP_ROWS	✓		
ERR_FST_MBA_BACKUP	✓		
ERR_FST_MBA_SKIP	✓		
ERR_PICTURE_END_UNEXPECTED	✓		
ERR_TST_PROGRAM	✓	✓	✓
ERR_NO_PROGRAM	✓	✓	✓
ERR_TST_END	✓	✓	✓
ERR_UCODE_ADDR	✓	✓	✓
ERR_NOT_IMPLEMENTED	✓	✓	✓

Table A.14.13 Parser error codes and the different standards (contd)



The state of the Video Demux register, continue, determines behavior after the event is cleared. If this register holds the value 0, then any remaining data in the DATA Token will be consumed by the Video Demux and no events will be generated. If the continue is set to 1, an event will be generated as each byte of extension or user data arrives at the Video Demux. This continues until the DATA Token is exhausted or continue is set to 0.

## NOTE: -

- 1) The first byte of the extension/user data is always presented via the rom\_revision register regardless of the state of continue.
- 2) There is no event indicating that the last byte of extension/user data has been read.

**A.14.7 Receiving Extra Information**

H.261 and MPEG allow information extending the coding standard to be embedded within pictures and groups of blocks (H.261) or slices (MPEG). The mechanism is different from that used for extension and user data (described in Section A.14.6). No start code precedes the data and, thus, it cannot be deleted by the Start Code Detector.

During H.261 operation, the Parser events ERR\_PSPARE and ERR\_GSPARE indicate the detection of this information. The corresponding events during MPEG operation are ERR\_EXTRA\_PICTURE and ERR\_EXTRA\_SLICE.

When the Parser event is generated, the first byte of the extra information is presented through the register, rom\_revision.

The state of the Video Demux register, continue, determines behavior after the event is cleared. If this register holds the value 0, then any remaining extra information will be consumed by the Video Demux and no events will be generated. If the continue is set to 1, an event will be generated as each byte of extra information arrives at the Video Demux. This continues until the extra information is exhausted or continue is set to 0.

## NOTE:

- 1) The first byte of the extension/user data is always presented via the rom\_revision

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→ register regardless of the state of  
continue.

2) There is no event indicating that the last  
byte of extension/user data has been  
read.

5

#### A.14.7.1 Generation of the FIELD\_INFO Token

During MPEG operation, if the register field\_info is set  
to 1, the first byte of any extra\_information\_picture is  
placed in the FIELD\_INFO Token. This behavior is not  
covered by the standardization activities of MPEG. Table  
A.3.2 shows the definition of the FIELD\_INFO Token.

If field\_info is set to 1, no Parser event will be  
generated for the first byte of extra\_information\_picture.  
However, events will be generated for any subsequent bytes  
of extra\_information\_picture. If there is only a single  
byte of extra\_information\_picture, no Parser event will  
occur.

15

#### A.14.8 Changes at the MPEG sequence layer

The MPEG sequence header describes the following  
characteristic of the video about to be decoded:

20

- horizontal and vertical size
- pixel aspect ratio
- picture rate
- coded data rate
- video buffer verifier buffer size

25

If any of these parameters change when the Spatial  
Decoder decodes a sequence header, the Parser event  
ERR\_MPEG\_SEQUENCE will be generated.

##### A.14.8.1 Change in picture size

If the picture size has changed, the user's software  
should read the values in horiz\_pels and vert\_pels and  
compute new values to be loaded into the registers  
horiz\_macroblocks and vert\_macroblocks.

30

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be used. However, use of the tables is quite different.

Two "types" of data are considered: intra and non-intra. A different table is used for each data type. Two "default" tables are defined by MPEG. One is for use with intra data and the other with non-intra data (see Table A.15.2 and Table A.15.3). These default tables must be written into the quantization table memory of the Spatial Decoder before MPEG decoding is possible.

MPEG also allows two "down loaded" quantization tables.

One is for use with intra data and the other with non-intra data. The values for these tables are contained in the MPEG data stream and will be loaded into the quantization table memory automatically.

The value output from the tables is modified by a scale factor.

#### A.15.2.2 Inverse quantizer registers

Register name	Size/Dir.	Reset State	Description
iq_access	1 rw	0	This access bit stops the operation of the inverse quantizer so that its various registers can be accessed reliably. See A.6.4.1
iq_coding_standard	2 rw	0	This register configures the coding standard used by the inverse quantizer. The register can be loaded directly or by a CODING_STANDARD Token. See A.21.1
iq_keyhole_address	8 rw	x	Keyhole access to the which holds the 4 quantizer tables. See A.6.4.3 for more information about accessing registers through a keyhole.
iq_keyhole_data	8 rw	x	

Table A.15.1 Inverse quantizer registers

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In the present invention, the iq\_access register must be set before the quantization table memory can be accessed. The quantization table memory will return the value zero if an attempt is made to read it while iq\_access is set to 0.

#### 5 A.15.2.3 Configuring the inverse quantizer

In normal operation, there is no need to configure the inverse quantizer's coding standard as this will be automatically configured by the CODING\_STANDARD Token.

For H.261 operation, the quantizer tables are not used.  
10 No special configuration is required. For JPEG operation, the tables required by the inverse quantizer should be automatically loaded with information extracted from the coded data.

MPEG operation requires that the default quantization  
15 tables are loaded. This should be done while iq\_access is set to 1. The values in Table A.15.2 should be written into locations 0x00 to 0x3F of the inverse quantizer's extended address space (accessible through the keyhole registers iq\_keyhole\_address and iq\_keyhole\_data).  
20 Similarly, the values in Table A.15.3 should be written into locations 0x40 to 0x7F of the inverse quantizer's extended address space.

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$i$	$W_{i,0}^a$	$i$	$W_{i,0}$	$i$	$W_{i,0}$	$i$	$W_{i,0}$
0	8	16	27	32	29	48	35
1	16	17	27	33	29	49	38
2	16	18	26	34	27	50	38
3	19	19	26	35	27	51	40
4	16	20	26	36	29	52	40
5	19	21	26	37	29	53	40
6	22	22	27	38	32	54	48
7	22	23	27	39	32	55	48
8	22	24	27	40	34	56	46
9	22	25	29	41	34	57	46
10	22	26	29	42	37	58	56
11	22	27	29	43	38	59	56
12	26	28	34	44	37	60	58
13	24	29	34	45	35	61	69
14	26	30	34	46	35	62	69
15	27	31	29	47	34	63	83

Table A.15.2 Default MPEG table for intra coded blocks

a. Offset from start of quantization table  
memory

b. Quantization table value.



$i$	$W_{i,1}$	$i$	$W_{i,1}$	$i$	$W_{i,1}$	$i$	$W_{i,1}$
0	16	16	16	32	16	48	16
1	16	17	16	33	16	49	16
2	16	18	16	34	16	50	16
3	16	19	16	35	16	51	16
4	16	20	16	36	16	52	16
5	16	21	16	37	16	53	16
6	16	22	16	38	16	54	16
7	16	23	16	39	16	55	16
8	16	24	16	40	16	56	16
9	16	25	16	41	16	57	16
10	16	26	16	42	16	58	16
11	16	27	16	43	16	59	16
12	16	28	16	44	16	60	16
13	16	29	16	45	16	61	16
14	16	30	16	46	16	62	16
15	16	31	16	47	16	63	16

Table A.15.3 Default MPEG table for non-intra coded blocks

#### A.15.2.4 configuring tables from Tokens

As an alternative to configuring the inverse quantizer tables via the MPI, they can be initialized by Tokens. These Tokens can be supplied via either the coded data port or the MPI.

The QUANT\_TABLE Token is described in Table A.3.2. It has a two bit field *tt* which specifies which of the 4 (0 to 3) table locations is defined by the Token. For MPEG operation, the default definitions of tables 0 and 1 need to be loaded.

#### A.15.2.5 quantization table values

For both JPEG and MPEG, the quantization table entries are 8 bit numbers. The values 255 to 1 are legal. The value 0 is illegal.

#### A.15.2.6 Number ordering of quantization tables

The ~~quantization~~ table values are used in "zig-zag" scan order (see the coding standards). The tables should be viewed as a one dimensional array of 64 values (rather than a 8x8 array). The table entries at lower addresses  
 5 correspond to the lower frequency DCT coefficients.

When quantization table values are carried by a QUANT\_TABLE Token, the first value after the Token header is the table entry for the "DC" coefficient.

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

## A.15.4.7 Inverse quantizer test registers

Register name	Size/Dir.	Reset State	Description
iq_quant_scale	5 rw		This register holds the current value of the quantisation scale factor. It is loaded by the QUANT_SCALE Token. This is not used during JPEG operation.
iq_component	2 rw		This register holds the two bit component ID taken from the most recent DATA Token head. This value is involved in the selection of the quantiser table.  The register will also hold the table ID after a QUANT_TABLE Token arrives to load the table.
iq_prediction_mode	2 rw		This holds the two LSBs of the most recent PREDICTION_MODE Token.
iq_jpeg_indirection	8 rw		This register relates the two bit component ID number of a DATA Token to the table number of the quantisation table that should be used.  Bits 1:0 specify the table number that will be used with component 0  Bits 3:2 specify the table number that will be used with component 1  Bits 5:4 specify the table number that will be used with component 2  Bits 7:6 specify the table number that will be used with component 3  This register is loaded by JPEG_TABLE_SELECT Tokens.
iq_mpeg_indirection	2 rw	0	This two bit register records whether to use default or down loaded quantisation tables with the intra and non-intra data.  A 0 in the bit position indicates that the default table should be used. A 1 indicates that a down loaded table should be used.  Bit 0 refers to intra data. Bit 1 refers to non-intra data. This register is normally loaded by the Token MPEG_TABLE_SELECT

Table A.15.4 Inverse quantiser test registers

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### A.15.3 Inverse Discrete Cosine Transform

The inverse discrete transform processor of the present invention meets the requirements set out in CCITT recommendation H.261, the IEEE specification P1180 and  
 5 complies with the requirements described in current draft revision of MPEG.

The inverse discrete cosine transform process is the same regardless of which coding standard is used. No, configuration by the user is required.

10 There are two events associated with the inverse discrete transform processor.

Register name	Size/Dir.	Reset State	Description
ldct_too_few_event	1 rw	0	The Inverse DCT requires that all DATA Tokens contain exactly 64 values. If less than 64 values are found then the too-few event will be generated. If the mask register is set to 1 then an interrupt can be generated and the Inverse DCT will halt.  This event should only occur following an error in the coded data.
ldct_too_few_mask	1 rw	0	
ldct_too_many_event	1 rw	0	The Inverse DCT requires that all DATA Tokens contain exactly 64 values. If more than 64 values are found then the too-many event will be generated. If the mask register is set to 1 then an interrupt can be generated and the inverse DCT will halt.  This event should only occur following an error in the coded data.
ldct_too_many_mask	1 rw	0	

Table A.15.5 Inverse DCT event registers

For a better understanding of the DCT and inverse DCT function the reader can examine any of the picture coding  
 15 standards.

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## SECTION A.16 Connecting to the output of Spatial

### Decoder

The output of the Spatial Decoder is a standard Token Port with 9 bit wide data words. See Section A.4 for more  
5 information about the electrical behavior of the interface.

The Tokens present at the output will depend on the coding standard employed. By way of example, this section of the disclosure looks at the output of the Spatial Decoder when configured for JPEG operation. This section  
10 also describes the Token sequence observed at the output of the Temporal Decoder during JPEG operation as the Temporal Decoder doesn't modify the Token sequence that results from decoding JPEG.

However, MPEG and H.261 both require the use of the  
15 Temporal Decoder. See section A.19 for information about connecting to the output of the Temporal Decoder when configured for MPEG and H.261 operation.

Furthermore, this section identifies which of the Tokens are available at the output of the Spatial Decoder and  
20 which are most useful when designing circuits to display that output. Other Tokens will be present, but are not needed to display the output and, therefore, are not discussed here.

This section concentrates on showing:

- 25     · How the start and end of sequences can be identified.
- How the start and end of pictures can be identified.
- How to identify when to display the picture.
- 30     · How to identify where in the display the picture data should be placed.

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### A.16.1 Structure of JPEG pictures

This section provides an overview of some features of the JPEG syntax. Please refer to the coding standard for full details.

5       JPEG provides a variety of mechanisms for encoding individual pictures. JPEG makes no attempt to describe how a collection of pictures could be encoded together to provide a mechanism for encoding video.

10       The Spatial Decoder, in accordance with the present invention, supports JPEG's *baseline sequential* mode of operation. There are three main levels in the syntax: Image, Frame and Scan. A sequential image only contains a single frame. A frame can contain between 1 and 256 different image (color) components. These image components  
15       can be grouped, in a variety of ways, into scans. Each scan can contain between 1 and 4 image components (see Figure 81 "Overview of JPEG baseline sequential structure").

20       If a scan contains a single image component, it is *non-interleaved*, if it contains more than one image component, it is an *interleaved* scan. A frame can contain a mixture of interleaved and non-interleaved scans. The number of scans that a frame can contain is determined by the 256 limit on the number of image components that a frame can  
25       contain.

      Within an interleaved scan, data is organized into minimum coding units (MCUs) which are analogous to the macroblock used in MPEG and H.261. These MCUs are raster ordered within a picture. In a non-interleaved scan, the  
30       MCU is a single 8x8 block. Again, these are raster organized.

      The Spatial Decoder can readily decode JPEG data containing 1 to 4 different color components. Files describing greater numbers of components can also be

### A.16.2 Token sequence

- 5       The JPEG markers codes are converted to an analogous  
MPEG named Token by the Start Code Detector (see Table  
A.11.4, see Fig. 82 "Tokenized JPEG picture").

## SECTION A.17 Temporal Decoder . .

- 30 MH, operation
- Provides temporal decoding for MPEG & H.261 video decoders
- H.261 CIF and QCIF formats
- 5 · MPEG video resolutions up to 704x480, 30 Hz, 4:2:0
- Flexible chroma sampling formats
- Can re-order the MPEG picture sequence
- Glue-less DRAM interface
- Single +5V supply
- 10 · 208 pin PQFP package
- Max. power dissipation 2.5W
- Uses standard page mode DRAM

The Temporal Decoder is a companion chip to the Spatial Decoder. It provides the temporal decoding required by

15 H.261 and MPEG.

The Temporal Decoder implements all the prediction forming features required by MPEG and H.261. With a single 4 Mb DRAM (e.g., 512 k x 8) the Temporal Decoder can decode CIF and QCIF H.261 video. With 8 Mb of DRAM (e.g., two 256

20 k x 16) the 704 x 480, 30Hz, 4:2:0 MPEG video can be decoded.

The Temporal Decoder is not required for Intra coding schemes (such as JPEG). If included in a multi-standard decoder, the Temporal Decoder will pass decoded JPEG

25 pictures through to its output.

**Note:** The above values are merely illustrative, by way of example and not necessarily by way of limitation, of one embodiment of the present invention. It will be appreciated that other values and ranges may also be used

30 without departing from the invention.

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## A.17.1 Temporal Decoder Signals

Signal Name	I/O	Pin Number	Description
in_data[8:0]	I	173, 172, 171, 169, 168, 167, 166, 164, 163	Input Port. This is a standard two wire interface normally connected to the
in_extn	I	174	Output Port of the Spatial Decoder
in_valid	I	162	See sections A.4 and A.18.1
in_accept	O	161	
enable[1:0]	I	126, 127	Micro Processor Interface (MPI)  See A.6.1 on page 59.
$\overline{rw}$	I	125	
addr[7:0]	I	137, 136, 135, 133, 132, 131, 130, 128	
data[7:0]	O	152, 151, 149, 147, 145, 143, 141, 140	
$\overline{irq}$	O	154	
DRAM_data[31:0]	I/O	15, 17, 19, 20, 22, 25, 27, 30, 31, 33, 35, 38, 39, 42, 44, 47, 49, 57, 59, 61, 63, 66, 68, 70, 72, 74, 76, 79, 81, 83, 84, 85	DRAM Interface.  See section A.5.2
DRAM_addr[10:0]	O	184, 186, 188, 189, 192, 193, 195, 197, 199, 200, 203	
$\overline{RAS}$	O	11	
$\overline{CAS}$ [3:0]	O	2, 4, 6, 8	
$\overline{WE}$	O	12	
$\overline{OE}$	O	204	
DRAM_enable	I	112	Output Port. This is a standard two wire interface.  See sections A.4 and A.19
out_data[7:0]	O	89, 90, 92, 93, 94, 95, 97, 98	
out_extn	O	87	
out_valid	O	99	
out_accept	I	100	JTAG port.  See section A.8
tck	I	115	
tdi	I	116	
tdo	O	120	
tms	I	117	
$\overline{trst}$	I	121	The main decoder clock. See Table A.7.2
decoder_clock	I	177	
$\overline{reset}$	I	160	Reset.

Table A.17.1 Temporal Decoder signals

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Signal Name	I/O	Pin Num.	Description
tp0ish	I	122	If override = 1 then tp0ish and tp1ish are inputs for the on-chip two phase clock.
tp1ish	I	123	
override	I	110	For normal operation set override = 0. tp0ish and tp1ish are ignored (so connect to GND or V <sub>DD</sub> ).
chiptest	I	111	Set chiptest = 0 for normal operation.
lloop	I	114	Connect to GND or V <sub>DD</sub> during normal operation.
ramtest	I	109	If ramtest = 1 test of the on-chip RAMs is enabled. Set ramtest = 0 for normal operation.
pllselect	I	178	If pllselect = 0 the on-chip phase locked loops are disabled. Set pllselect = 1 for normal operation.
tl	I	180	Two clocks required by the DRAM interface during test operation. Connect to GND or V <sub>DD</sub> during normal operation.
lq	I	179	
pdout	O	207	These two pins are connections for an external filter for the phase lock loop.
pdin	I	206	

Table A.17.2 Temporal Decoder Test signals

Signal Name	Pin	Signal Name	Pin	Signal Name	Pin	Signal Name	Pin
nc	208	nc	156	nc	104	nc	52
test pin	207	nc	155	nc	103	nc	51
test pin	206	irq	154	nc	102	nc	50
GND	205	nc	153	v <sub>DD</sub>	101	DRAM_data[15]	49
OE	204	data[7]	152	out_accept	100	nc	48
DRAM_addr[0]	203	data[6]	151	out_valid	99	DRAM_data[16]	47
v <sub>DD</sub>	202	nc	150	out_data[0]	98	nc	46
nc	201	data[5]	149	out_data[1]	97	GND	45
DRAM_addr[1]	200	nc	148	GND	96	DRAM_data[17]	44
DRAM_addr[2]	199	data[4]	147	out_data[2]	95	nc	43
GND	198	GND	146	out_data[3]	94	DRAM_data[18]	42
DRAM_addr[3]	197	data[3]	145	out_data[4]	93	v <sub>DD</sub>	41
nc	196	nc	144	out_data[5]	92	nc	40

Table A.17.3 Temporal Decoder Pin Assignments

Signal Name	Pin	Signal Name	Pin	Signal Name	Pin	Signal Name	Pin
DRAM_addr[4]	195	data[2]	143	vdd	91	DRAM_data[19]	39
vdd	194	nc	142	out_data[6]	90	DRAM_data[20]	38
DRAM_addr[5]	193	data[1]	141	out_data[7]	89	nc	37
DRAM_addr[6]	192	data[0]	140	nc	88	GND	36
nc	191	nc	139	out_extn	87	DRAM_data[21]	35
GND	190	vdd	138	GND	86	nc	34
DRAM_addr[7]	189	addr[7]	137	DRAM_data[0]	85	DRAM_data[22]	33
DRAM_addr[8]	188	addr[6]	136	DRAM_data[1]	84	vdd	32
vdd	187	addr[5]	135	DRAM_data[2]	83	DRAM_data[23]	31
DRAM_addr[9]	186	GND	134	vdd	82	DRAM_data[24]	30
nc	185	addr[4]	133	DRAM_data[3]	81	nc	29
DRAM_addr[10]	184	addr[3]	132	nc	80	GND	28
GND	183	addr[2]	131	DRAM_data[4]	79	DRAM_data[25]	27
nc	182	addr[1]	130	GND	78	nc	26
vdd	181	vdd	129	nc	77	DRAM_data[26]	25
test pin	180	addr[0]	128	DRAM_data[5]	76	nc	24
test pin	179	enable[0]	127	nc	75	vdd	23
test pin	178	enable[1]	126	DRAM_data[6]	74	DRAM_data[27]	22
decoder_clock	177	n $\bar{w}$	125	vdd	73	nc	21
nc	176	GND	124	DRAM_data[7]	72	DRAM_data[28]	20
GND	175	test pin	123	nc	71	DRAM_data[29]	19
in_extn	174	test pin	122	DRAM_data[8]	70	GND	18
in_data[8]	173	trst	121	GND	69	DRAM_data[30]	17
in_data[7]	172	tdo	120	DRAM_data[9]	68	nc	16
in_data[6]	171	nc	119	nc	67	DRAM_data[31]	15
vdd	170	vdd	118	DRAM_data[10]	66	vdd	14
in_data[5]	169	tms	117	vdd	65	nc	13
in_data[4]	168	tdi	116	nc	64	$\overline{WE}$	12
in_data[3]	167	lck	115	DRAM_data[11]	63	$\overline{RAS}$	11
in_data[2]	166	test pin	114	nc	62	nc	10
GND	165	GND	113	DRAM_data[12]	61	GND	9
in_data[1]	164	DRAM_enable	112	GND	60	$\overline{CAS}[0]$	8
in_data[0]	163	test pin	111	DRAM_data[13]	59	nc	7
in_valid	162	test pin	110	nc	58	$\overline{CAS}[1]$	6
in_accept	161	test pin	109	DRAM_data[14]	57	vdd	5

Table A.17.3 Temporal Decoder Pin Assignments (contd)

Signal Name	Pin	Signal Name	Pin	Signal Name	Pin	Signal Name	Pin
reset	160	nc	108	v <sub>DD</sub>	56	CAS[2]	4
v <sub>DD</sub>	159	nc	107	nc	55	nc	3
nc	158	nc	106	nc	54	CAS[3]	2
nc	157	nc	105	nc	53	nc	1

**Table A.17.3 Temporal Decoder Pin Assignments (contd)**

#### A.17.1.1 "nc" no connect pins

5 The pins labelled nc in Table A.17.3 are not currently used in the present invention and are reserved for future products. These pins should be left unconnected. They should not be connected to  $V_{DD}$ , GND, each other or any other signal.

#### A.17.1.2 $V_{DD}$ and GND pins

10 As will be appreciated all the  $V_{DD}$  and GND pins provided must be connected to the appropriate power supply. The device will not operate correctly unless all the  $V_{DD}$  and GND pins are correctly used.

#### A.17.1.3 Test pin connections for normal operation

15 Nine pins on the Temporal Decoder are reserved for internal test use.

Pin number	Connection
	Connect to GND for normal operation
	Connect to $V_{DD}$ for normal operation
	Leave Open Circuit for normal operation

**Table A.17.4 Default test pin connections**

# A.17.4 - JTAG pins for normal operation

See Section A.8.1.

Addr. (hex)	Register Name	See table
0x00 ... 0x01	Interrupt service area	A.17.6
0x02 ... 0x07	Not used	
0x08	Chip access	A.17.7
0x09 ... 0x0F	Not used	
0x10	Picture sequencing	A.17.8
0x11 ... 0x1F	Not used	
0x20 ... 0x2E	DRAM interface configuration registers	A.17.9
0x2F ... 0x3F	Not used	
0x40 ... 0x53	Buffer configuration	A.17.3
0x54 ... 0x5F	Not used	
0x60 ... 0xFF	Test registers	A.17.11

Table A.17.5 Overview of Temporal Decoder memory map

Addr. (hex)	Bit num.	Register Name	Page references
0x00	7	chip_event	
	6:2	not used	
	1	chip_stopped_event	
	0	count_error_event	
0x01	7	chip_mask	
	6:2	not used	
	1	chip_stopped_mask	
	0	count_error_mask	

Table A.17.6 Interrupt service area registers

Addr. (hex)	Bit num.	Register Name	Page references
0x08	7:1	not used	
	0	chip_access	

Table A.17.7 Chip access register

Addr. (hex)	Bit num.	Register Name	Page references
0x10	7:1	not used	
	0	MPEG_reordering	

Table A.17.8 Picture sequencing

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Addr. (hex)	Bit num.	Register Name	Page references
0x20	7:5	not used	
	4:0	page_start_length(4:0)	
0x21	7:4	not used	
	3:0	read_cycle_length(3:0)	
0x22	7:4	not used	
	3:0	write_cycle_length(3:0)	
0x23	7:4	not used	
	3:0	refresh_cycle_length(3:0)	
0x24	7:4	not used	
	3:0	CAS_falling(3:0)	
0x25	7:4	not used	
	3:0	RAS_falling(3:0)	
0x26	7:1	not used	
	0	interface_timing_access	
0x27	7:0	not used	
0x28	7:6	RAS_strength(2:0)	
	5:3	OEWE_strength(3:0)	
	2:0	DRAM_data_strength(3:0)	
0x29	7	not used	
	6:4	DRAM_addr_strength(3:0)	
	3:1	CAS_strength(3:0)	
	0	RAS_strength(3)	

Table A.17.9 DRAM interface configuration registers

Addr. (hex)	Bit num.	Register Name	Page references
0x28	7	not used	
	6:4	DRAM_addr_strength[3:0]	
	3:1	CAS_strength[3:0]	
	0	RAS_strength[3]	
0x29	7:6	RAS_strength[2:0]	
	5:3	OEWE_strength[3:0]	
	2:0	DRAM_data_strength[3:0]	
0x2A	7:0	refresh_interval	
0x2B	7:0	not used	
0x2C	7:6	not used	
	5	DRAM_enable	
	4	no_refresh	
	3:2	row_address_bits[1:0]	
	1:0	DRAM_data_width[1:0]	
0x2D	7:0	not used	
0x2E	7:0	Test registers	

**Table A.17.9 DRAM interface configuration registers (contd)**

Addr. (hex)	Bit num.	Register Name	Page references
0x40	7:0	not used	
0x41	7:2		
	1:0	picture_buffer_0[17:0]	
0x42	7:0		
0x43	7:0		
0x44	7:0	not used	
0x45	7:2		
	1:0	picture_buffer_1[17:0]	
0x46	7:0		
0x47	7:0		

**Table A.17.10 Buffer configuration registers**



Addr. (hex)	Bit num.	Register Name	Page references
0x48	7:0	not used	
0x49	7:1		
	0	component_offset_0[16:0]	
0x4A	7:0		
0x4B	7:0		
0x4C	7:0	not used	
0x4D	7:1		
	0	component_offset_1[16:0]	
0x4E	7:0		
0x4F	7:0		
0x50	7:0	not used	
0x51	7:1		
	0	component_offset_2[16:0]	
0x52	7:0		
0x53	7:0		

Table A.17.10 Buffer configuration registers (contd)

Addr. (hex)	Bit num.	Register Name	Page references
0x2E	7 ... 4	PLL resistors	
	3 ... 0		
0x60	7 ... 6	not used	
	5 ... 4	coding_standard[1:0]	
	3 ... 2	picture_type[1:0]	
	1	H261_filt	
	0	H261_s_f	
0x61	7 ... 6	component_id	
	5 ... 4	prediction_mode	
	3 ... 0	max_sampling	
0x62	7 ... 0	samp_h	
0x63	7 ... 0	samp_v	

Table A.17.11 Test registers

Addr. (hex)	Bit num.	Register Name	Page references
0x64	7 ... 0	back_h	
0x65	7 ... 0		
0x66	7 ... 0	back_v	
0x67	7 ... 0		
0x68	7 ... 0	forw_h	
0x69	7 ... 0		
0x6A	7 ... 0	forw_v	
0x6B	7 ... 0		
0x6C	7 ... 0	width_in_mo	
0x6D	7 ... 0		

Table A.17.11 Test registers (contd)

Table A.17.11 Test registers (contd)

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## SECTION A.18 Temporal Decoder Operation

### A.18.1 Data input

The input data port of the Temporal Decoder is a standard Token Port with 9 bit wide data words. In most applications, this will be connected directly to the output Token Port of the Spatial Decoder. See Section A.4 for more information about the electrical behavior of this interface.

### A.18.2 Automatic configuration

Parameters relating to the coded video's picture format are automatically loaded into registers within the Temporal Decoder by Tokens generated by the Spatial Decoder.

Token	Configuration performed
<b>CODING_STANDARD</b>	The coding standard of the Temporal Decoder is automatically configured by the <b>CODING_STANDARD</b> Token. This is generated by the Spatial Decoder each time a new sequence is started. See Figure 58
<b>DEFINE_SAMPLING</b>	The horizontal and vertical chroma sampling information for each of the color components is automatically configured by <b>DEFINE_SAMPLING</b> Tokens.
<b>HORIZONTAL_MBS</b>	The horizontal width of pictures in macro blocks is automatically configured by <b>HORIZONTAL_MBS</b> Token.

**Table A.18.1 Configuration of Temporal Decoder via Tokens**

### A.18.3 Manual configuration

The user must configure (via the microprocessor interface) application dependent factors.

**A.18.3.1 When to configure**

The Temporal Decoder should only be configured when no data processing is taking place. This is the default state after reset is removed. The Temporal Decoder can be

5 stopped to allow re-configuration by writing 1 to the chip\_access register. After configuration is complete, 0 should be written to chip\_access.

See Section A.5.3 for details of when to configure the DRAM interface.

10 **A.18.3.2 DRAM interface**

The DRAM interface timing must be configured before it is possible to decode predictively coded video (e.g., H.261 or MPEG). See Section A.5, "DRAM Interface".

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Table A.18.2 Temporal Decoder registers

### A.18.3.3 Numbers in picture buffer registers

The picture buffer pointers (18 bit) and the component offset (17 bit) registers specify a block (8x8 bytes) address, not a byte address.

#### 5 A.18.3.4 Picture buffer allocation

To decode predictively coded video (either H.261 or MPEG) the Temporal Decoder must manage two picture buffers. See Section A.18.4 and A.18.4.4 for more information about how these buffers are used.

10 The user must ensure that there is sufficient memory above each of the picture buffer pointers (picture\_buffer\_0 and picture\_buffer\_1) to store a single picture of the required video format (without overlapping with the other picture buffer). Normally, one of the picture buffer  
15 pointers will be set to 0 (i.e., the bottom of memory) and the other will be set to point to the middle of the memory space.

##### A.18.3.4.1 Normal configuration for MPEG or H.261

H.261 and MPEG both use a 4:1:1 ratio between the  
20 different color components (i.e., there are 4 times as many luminance pels as there are pels in either of the chrominance components).

As documented in Section A.3.5.1, "Component Identification number", component 0 will be the luminance  
25 component and components 1 and 2 will be chrominance.

An example configuration of the component offset registers is to set component\_offset\_0 to 0 so that component 0 starts at the picture buffer pointer. Similarly, component\_offset\_1 could be set to 4/6 of the  
30 picture buffer size and component\_offset\_2 could be set to 5/6 of the picture buffer size.

#### A.18.3.5 Picture sequence re-ordering

MPEG uses three different picture types: Intra (I),

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Predicted (P) and Bidirectionally interpolated (B). B pictures are based on predictions from two pictures: one from the future and one from the past. The picture order is modified at the encoder so that I and P picture can be  
 5 decoded from the coded data before they are required to decode B pictures.

The picture sequence must be corrected before these pictures can be displayed. The Temporal Decoder can provide this picture re-ordering (by setting register  
 10 MPEG\_reordering = 1). Alternatively, the user may wish to implement the picture re-ordering as part of his display interface function. Configuring the Temporal Decoder to provide picture re-ordering may reduce the video resolution that can be decoded, see Section A.18.5.

#### 15 **A.18.4 Prediction forming**

The prediction forming requirements of H.261 decoding and MPEG decoding are quite different. The CODING\_STANDARD Token automatically configures the Temporal Decoder to accommodate the prediction requirements of the different  
 20 standards.

##### **A.18.4.1 JPEG Operation**

When configured for JPEG operation no predictions are performed since JPEG requires no temporal decoding.

##### **A.18.4.2 H.261 Operation**

25 In H.261, predictions are only from the picture just decoded. Motion vectors are only specified to integer pixel accuracy. The encoder can specify that a low pass filter be applied to the result of any prediction.

As each picture is decoded, it is written in to a  
 30 picture buffer in the off-chip DRAM so that it can be used in decoding the next picture. Decoded pictures appear at the output of the Temporal Decoder as they are written into the off-chip DRAM.

For full details of prediction, and the arithmetic

operations involved, the reader is directed to the H.261 standard. The Temporal Decoder of the present invention is fully compliant with the requirements of H.261.

#### **A.18.4.3 MPEG Operation (without re-ordering)**

5 The operation of the Temporal Decoder changes for each of the three different MPEG picture types (I, P and B).

"I" pictures require no further decoding by the Temporal Decoder, but must be stored in a picture buffer (frame store) for later use in decoding P and B pictures.

10 Decoding P pictures requires forming predictions from a previously decoded P or I picture. The decoded P picture is stored in a picture buffer for use in decoding P and B pictures. MPEG allows motion vectors specified to half pixel accuracy. On-chip filters provide interpolation to support this half pixel accuracy.

15 B pictures can require predictions from both of the picture buffers. As with P pictures, half pixel motion vector resolution accuracy requires on chip interpolation of the picture information. B pictures are not stored in the off-chip buffers. They are merely transient.

20 All pictures appear at the output port of the Temporal Decoder as they are decoded. So, the picture sequence will be the same as that in the coded MPEG data (see the upper part of Figure 85).

25 For full details of prediction, and the arithmetic operations involved, the reader is directed to the proposed MPEG standard draft. These requirements are met by the Temporal Decoder of the present invention.

#### **A.18.4.4 MPEG Operation (with re-ordering)**

30 When configured for MPEG operation with picture re-ordering (MPEG\_reordering = 1), the prediction forming operations are as described above in Section A.18.4.3. However, additional data transfers are performed to re-order the picture sequence.





lower memory bandwidth requirements. For example, using only integer resolution motion vectors or, alternatively, not using B pictures, significantly reduce the memory bandwidth requirements. Such subsets are not analyzed here.

#### A.18.5.1 Characteristics of DRAM interface

The number of cycles taken to transfer data across the DRAM interface depends on a number of factors:

- The timing configuration of the DRAM interface to suite the DRAM employed
- The data bus width (8, 16 or 32 bits)
- The type of data transfer:
  - 8x8 block read or write
  - for prediction to half pixel accuracy
  - for prediction to integer pixel accuracy

See section A.5, "DRAM Interface", for more information about the detail configuration of the DRAM interface.

Table A.18.3 shows how many DRAM interface "cycles" are required for each type of data transfer.

Data bus width (bits)	read or write 8x8 block	form prediction (half pixel accuracy)	form prediction (integer pixel accuracy)
8	1 page address + 64 transfers	4 page address + 81 transfers	4 page address + 64 transfers
16	1 page address + 32 transfers	4 page address + 45 transfers	4 page address + 40 transfers
32	1 page address + 16 transfers	4 page address + 27 transfers	4 page address + 24 transfers

Table A.18.3 Data transfer times for Temporal Decoder

Table A.18.4 takes the figures in Table A.18.3 and evaluates them for a "typical" DRAM. In this example, a 27 MHz clock is assumed. It will be appreciated that while 27 MHz is used here, it is not intended as a limitation. The access start takes 11 ticks (102ns) and the data transfer takes 6 ticks (56 ns).

#### A.18.5.2 MPEG resolution without re-ordering

The peak memory bandwidth load occurs when decoding B pictures. In a "worst case" scenario, the B frame may be formed from predictions from both the picture buffers with all predictions being to half pixel accuracy.

Data bus width (bits)	read or write 8x8 block	form prediction (half pixel accuracy)	form prediction (integer pixel accuracy)
8	3657 ns	4907 ns	3963 ns
16	1880 ns	2907 ns	2195 ns
32	991 ns	1907 ns	1741 ns

**Table A.18.4 Illustration with "typical" DRAM**

Using the example figures from Table A.18.4, it can be seen that it will take the DRAM interface 3815 ns to read the data required for two accurate half pixel accurate predictions (via a 32 bit wide interface). The resolution that the Temporal Decoder can support is determined by the number of these predictions that can be performed within one picture time. In this example, the Temporal Decoder can process 8737 8x8 blocks in a single 33 ms picture period (e.g., for 30 Hz video).

If ~~the~~ required video format is 704 x 480, then each picture contains 7920 8 x 8 blocks (taking into consideration the 4:2:0 chroma sampling). It can be seen that this video format consumes approx. 91% of the available DRAM interface bandwidth (before any other factors such as DRAM refresh are taken into consideration). Accordingly, the Temporal Decoder can support this video format.

#### A.18.5.3 MPEG resolution with re-ordering

When MPEG picture re-ordering is employed the worst case scenario is encountered while P pictures are being decoded. During this time, there are 3 loads on the DRAM interface:

- form predictions
- write back the result
- read out the previous P or I picture

Using the example figures from Table A.18.3, we can find the time it takes for each of these tasks when a 32 bit wide interface is available. Forming the prediction takes 1907 ns/n while the read and the write each take 991 ns, a total of 3889 ns. This permits the Temporal Decoder to process 8485 8 x 8 blocks in a 33 ms period.

Hence, processing 704 x 480 video will use approximately 93% of the available memory bandwidth (ignoring refresh).

#### A.18.5.4 H.261

H.261 only supports two picture formats CIF (352 x 288) and QCIF (172 x 144) at picture rates up to 30 Hz. A CIF picture contains 2376 8 x 8 blocks. The only memory operations required are the writing of 8 x 8 blocks and the forming of predictions with integer accuracy motion vectors.

Using the example figures from Table A.18.4 for an 8 bit wide memory interface, it can be seen that writing each block will take 3657 ns while forming the prediction for one block will take 3963 ns/n, a total of 7620 ns per



## SECTION A.19 Connecting to the output of the Temporal Decoder

The output of the Temporal Decoder is a standard Token Port with 8 bit wide data words. See Section A.4 for more  
5 information about the electrical behavior of the interface.

The Tokens present at the output of the Temporal Decoder will depend on the coding standard employed and, in the case of MPEG, whether the pictures are being re-ordered. This section identifies which of the Tokens are available  
10 at the output of the Temporal decoder and which are the most useful when designing circuits to display that output. Other Tokens will be present, but are not needed to display the output and, therefore they are not discussed here.

This section concentrates on showing:

- 15     · How the start and end of sequences can be identified.
- How the start and end of pictures can be identified.
- How to identify when to display the picture.
- How to identify where in the display the picture data should be placed.

### 20     A.19.1 JPEG output

The Token sequence output by the Temporal Decoder when decoding JPEG data is identical to that seen at the output of Spatial Decoder. Recall, JPEG does not require  
processing by the Temporal Decoder. However, the Temporal  
25 Decoder tests intra data Tokens for negative values (resulting from the finite arithmetic precision of the IDCT in the Spatial Decoder) and replaces them with zero.

See Section A.16 for further discussion of the output sequence observed during JPEG operation.

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### **A.19.2 ~~H.261~~ Output**

#### **A.19.2.1 Start and end of sessions**

H.261 doesn't signal the start and end of the video stream within the video data. Nevertheless, this is implied by the application. For example, the sequence starts when the telecommunication connection is made and ends when the line is dropped. Thus, the highest layer in the video syntax is the "picture layer".

The Start Code Detector of the Spatial Decoder in accordance with the invention, allows SEQUENCE\_START and CODING\_STANDARD Tokens to be inserted automatically before the first PICTURE\_START. See sections A.11.7.3 and A.11.7.4.

At the end of an H.261 session (e.g., when the line is dropped) the user should insert a FLUSH Token after the end of the coded data. This has a number of effects (see Appendix A.31.1:

- It ensures that PICTURE\_END is generated to signal the end of the last picture.
- It ensures that the end of the coded data is pushed through the decoder.

#### **A.19.2.2 Acquiring pictures**

Each picture is composed of a hierarchy of elements referred to as layers in the syntax. The sequence of Tokens at the output of the Temporal Decoder when decoding H.261 reflects this structure.

#### **A.19.2.1 Picture layer**

Each picture is preceded by a PICTURE\_START Token and each is immediately followed by a PICTURE\_END Token. H.261 doesn't naturally contain a picture end. This Token is inserted automatically by the Start Code Detector of the Spatial Decoder.

After the PICTURE\_START Token, there will be TEMPORAL\_REFERENCE and PICTURE\_TYPE Tokens. The

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TEMPORAL\_REFERENCE Token carries a 10 bit number (of which only the 5 LSBs are used in H.261) that indicates when the picture should be displayed. This should be studied by any display system as H.261 encoders can omit pictures from the sequence (to achieve lower data rates). Omission of pictures can be detected by the temporal reference incrementing by more than one between successive pictures.

Next, the PICTURE\_TYPE Token carries information about the picture format. A display system may study this information to detect if CIF or QCIF pictures are being decoded. However, information about the picture format is also available by studying registers within the Huffman decoder.

<Xref to Huffman decoder section>

#### 15 A.19.2.2.2 Group of Blocks Layer

Each H.261 picture is composed of a number of "groups of blocks". Each of these is preceded by a SLICE\_START Token (derived from the H.261 group number and group start code). This Token carries an 8 bit value that indicates where in the display the group of blocks should be placed. This provides an opportunity for the decoder to resynchronize after data errors. Moreover, it provides the encoder with a mechanism to skip blocks if there are areas of a picture that do not require additional information in order to describe them. By the time SLICE\_START reaches the output of the Temporal Decoder, this information is effectively redundant as the Spatial Decoder and Temporal Decoder have already used the information to ensure that each picture contains the correct number of blocks and that they are in the correct positions. Hence, it should be possible to compute where to position a block of data output by the Temporal Decoder just by counting the number of blocks that have been output since the start of the picture.

The number carried by SLICE\_START is one less than the



H.261 group of blocks number (see the H.261 standard for more information). Figure 94 shows the positioning of H.261 groups of blocks within CIF and QCIF pictures. NOTE: in the present invention, the block numbering shown is the same as that carried by SLICE\_START. This is different from the H.261 convention for numbering these groups.

Between the SLICE\_START (which indicates the start of each group of blocks) and the first macroblock there may be other Tokens. These can be ignored as they are not required to display the picture data.

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#### **A.19.2.2.3 Macroblock layer**

The sequence of macroblocks within each group of blocks is defined by H.261. There is no special Token information describing the position of each macroblock. The user  
 5 should count through the macroblock sequence to determine where to display each piece of information.

Figure 96 shows the sequence in which macroblocks are placed in each group of blocks.

Each macroblock contains 6 DATA Tokens. The sequence of  
 10 DATA Tokens in each group of 6 is defined by the H.261 macroblock structure. Each DATA Token should contain exactly 64 data bytes for an 8x8 area of pixels of a single color component. The color component is carried in a 2 bit number in the DATA Token (see section A.3.5.1). However,  
 15 the sequence of the color components in H.261 is defined.

Each group of DATA Tokens is preceded by a number of Tokens communicating information about motion vectors, quantizer scale factors and so forth. These Tokens are not required to allow the pictures to be displayed and, thus,  
 20 can be ignored.

Each DATA Token contains 64 data bytes for an 8x8 of a single color component. These are in a raster order.

#### **A.19.3 MPEG output**

MPEG has more layers in its syntax. These embody  
 25 concepts such as a video sequence and the group of pictures.

##### **A.19.3.1 MPEG Sequence layer**

A sequence can have multiple entry points (sequence starts) but should have only a single exit point (sequence end). When an MPEG sequence header code is decoded, the  
 30 Spatial Decoder generates a CODING\_STANDARD Token followed by a SEQUENCE\_START Token.

After the SEQUENCE\_START, there will be a number of

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Tokens of sequence header information that describe the video format and the like. See the draft MPEG standard for the information that is signalled in the sequence header and Table A.3.2 for information about how this data is converted into Tokens. This information describing the video format is also available in registers in the Huffman decoder.

This sequence header information may occur several times within an MPEG sequence, if that sequence has several entry points.

#### A.19.3.2 Group of pictures layer

An MPEG group of pictures provides a different type of "entry" point to that provided at a sequence start. The sequence header provides information about the picture/video format. Accordingly, if the decoder has no knowledge of the video format used in a sequence, it must start at a sequence start. However, once the video format is configured into the decoder, it should be possible to start decoding at any group of pictures.

MPEG doesn't limit the number of pictures in a group. However, in many applications a group will correspond to about 0.5 seconds, as this provides a reasonable granularity of random access.

The start of a group of pictures is indicated by a GROUP\_START Token. The header information provided after GROUP\_START includes two useful Tokens: TIME\_CODE and BROKEN\_CLOSED.

TIME\_CODE carries a subset of the SMPTE time code information. This may be useful in synchronizing the video decoder to other signals. BROKEN\_CLOSED carries the MPEG closed\_gap and broken\_link bits. See Section A.19.3.8 for more on the implications of random access and decoding edited video sequences.

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### A.19.3-3 - Picture layer

The start of a new picture is indicated by the PICTURE\_START Token. After this Token, there will be TEMPORAL\_REFERENCE and PICTURE\_TYPE Tokens. The temporary reference information may be useful if the Temporal Decoder is not configured to provide picture re-ordering. The picture type information may be useful if a display system wants to specially process B pictures at the start of an open GOP (see Section A.19.3.8).

10 Each picture is composed of a number of slices.

#### A.19.3.4 Slice layer

Section A.19.2.2.2 discusses the group of blocks used in H.261. The slice in MPEG serves a similar function. However, the slice structure is not fixed by the standard. The 8 bit value carried by the SLICE\_START Token is one less than the "slice vertical position" communicated by MPEG. See the draft MPEG standard for a description of the slice layer.

By the time SLICE\_START reaches the output of the  
20 Temporal Decoder, this information is effectively redundant  
since the Spatial Decoder and Temporal Decoder have already  
used the information to ensure that each picture contains  
the correct number of blocks in the correct positions.  
Hence, it should be possible to compute where to position a  
25 block of data output by the Temporal Decoder just by  
counting the number of blocks that have been output since  
the start of the picture.

See section A.19.3.7 for discussion of the effects of using MPEG picture re-ordering.

30     A.19.3.5    Macroblock layer

Each macroblock contains 6 blocks. These appear at the output of the Temporal Decoder in raster order (as specified by the draft MPEG specification).

### A.19.3.6 Block layer

Each macroblock contains 6 DATA Tokens. The sequence of DATA Tokens in each group of 6 is defined by the draft MPEG specification (this is the same as the H.261 macroblock structure). Each DATA token should contain exactly 64 data bytes for an 8 x 8 area of pixels of a single color component. The color component is carried in a 2 bit number in the DATA Token (see A.3.5.1). However, the sequence of the color components in MPEG is defined.

Each group of DATA Tokens is preceded by a number of Tokens communicating information about motion vectors, quantizer scale factors, and so forth. These Tokens are not required to allow the pictures to be displayed and, therefore, they can be ignored.

### 15 A.19.3.7 Effect of MPEG picture re-ordering

As described in A.18.3.5, the Temporal Decoder can be configured to provide MPEG picture re-ordering (MPEG\_reordering=1). The output of P and I pictures is delayed until the next P/I picture in the data stream starts to be decoded by the Temporal Decoder. At the output of the Temporal Decoder the DATA Tokens of the newly decoded P/I picture are replaced with DATA Tokens from the older P/I picture.

When re\_ordering P/I pictures, the PICTURE\_START, TEMPORAL\_REFERENCE and PICTURE\_TYPE Tokens of the picture are stored temporarily on-chip as the picture is written into the off-chip picture buffers. When the picture is read out for display, these stored Tokens are retrieved. Accordingly, re-ordered P/I pictures have the correct values for PICTURE\_START, TEMPORAL\_REFERENCE and PICTURE\_TYPE.

All other tokens below the picture layer are not re-ordered. As the re-ordered P/I picture is read-out for

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#### A.19.3.8 Random access and edited sequences

A.19.3.8.1 Open GOPs

20 If a decoder starts decoding the video at the first GOP,  
it will have no problems when it encounters the second GOP  
even if that GOP is open since it will have already decoded  
the P picture 16. However, if the decoder makes a random  
access and starts decoding at the second GOP it cannot  
decode B17 and B18 if they depend on P16 (i.e., if the GOP  
25 is open).

If the Spatial Decoder of the present invention encounters an open GOP as the first GOP following a reset or it receives a FLUSH Token, it will assume that a random access to an open GOP has occurred. In this case, the Huffman decoder will consume the data for the B pictures in the normal way. However, it will output B pictures predicted with (0,0) motion vectors off the I picture. The result will be that pictures B17 and B18 (in the example above) will be identical to I19.



or "~~substitutes~~" that have been introduced by the Spatial Decoder. Some applications may wish to take special measures when these "substitute" pictures are present.

[illegible]



## SECTION A.20 Late Write DRAM Interface

The interface is configurable in two ways:

- The detail timing of the interface can be configured to accommodate a variety of different DRAM types
- 5 · The "width" of the DRAM interface can be configured to provide a cost/performance trade-off

Signal Name	Input / Output	Description
DRAM_data(31:0)	I/O	The 32 bit wide DRAM data bus. Optionally this bus can be configured to be 16 or 8 bits wide.
DRAM_addr(10:0)	O	The 22 bit wide DRAM interface address is time multiplexed over this 11 bit wide bus.
RAS	O	The DRAM Row Address Strobe signal
CAS(3:0)	O	The DRAM Column Address Strobe signal. One signal is provided per byte of the interface's data bus. All the CAS signals are driven simultaneously.
WE	O	The DRAM Write Enable signal
OE	O	The DRAM Output Enable signal
DRAM_enable	I	This input signal, when low, makes all the output signals on the interface go high impedance and stops activity on the DRAM interface.

Table A.20.1 DRAM interface signals

Register name	Size/ Dir.	Reset State	Description
modify_DRAM_timing	1 bit rw	0	This function enable register allows access to the DRAM interface timing configuration registers. The configuration registers should not be modified while this register holds the value zero. Writing a one to this register requests access to modify the configuration registers. After a zero has been written to this register the DRAM interface will start to use the new values in the timing configuration registers.

Table A.20.2 DRAM Interface configuration registers

Register name	Size/ Dir.	Reset State	Description
page_start_length	5 bit rw	0	Specifies the length of the access start in ticks. The minimum value that can be used is 4 (meaning 4 ticks). 0 selects the maximum length of 32 ticks.
read_cycle_length	4 bit rw	0	Specifies the length of the fast page read cycle in ticks. The minimum value that can be used is 4 (meaning 4 ticks). 0 selects the maximum length of 16 ticks.
write_cycle_length	4 bit rw	0	Specifies the length of the fast page late write cycle in ticks. The minimum value that can be used is 4 (meaning 4 ticks). 0 selects the maximum length of 16 ticks.
refresh_cycle_length	4 bit rw	0	Specifies the length of the refresh cycle in ticks. The minimum value that can be used is 4 (meaning 4 ticks). 0 selects the maximum length of 16 ticks.
RAS_falling	4 bit rw	0	Specifies the number of ticks after the start of the access start that $\overline{RAS}$ falls. The minimum value that can be used is 4 (meaning 4 ticks). 0 selects the maximum length of 16 ticks.
CAS_falling	4 bit rw	8	Specifies the number of ticks after the start of a read cycle, write cycle or access start that $\overline{CAS}$ falls. The minimum value that can be used is 1 (meaning 1 tick). 0 selects the maximum length of 16 ticks.
DRAM_data_width	2 bit rw	0	Specifies the number of bits used on the DRAM interface data bus $DRAM\_data[31:0]$ . See A.20.4
row_address_bits	2 bit rw	0	Specifies the number of bits used for the row address portion of the DRAM interface address bus. See A.20.5
DRAM_enable	1 bit rw	1	Writing the value 0 in to this register forces the DRAM interface into a high impedance state.  0 will be read from this register if either the $DRAM\_enable$ signal is low or 0 has been written to the register.

Table A.20.2 DRAM Interface configuration registers (contd)

Register name	Size/ Dir.	Reset State	Description
refresh_interval	8 bit rw	0	This value specifies the interval between refresh cycles in periods of 16 decoder_clock cycles. Values in the range 1..255 can be configured. The value 0 is automatically loaded after reset and forces the DRAM interface to continuously execute refresh cycles until a valid refresh interval is configured. It is recommended that refresh_interval should be configured <i>only once</i> after each reset.
no_refresh	1 bit rw	0	Writing the value 1 to this register prevents execution of any refresh cycles.
CAS_strength	3 bit rw	6	These three bit registers configure the output drive strength of DRAM interface signals.  This allows the interface to be configured for various different loads  See A.20.8
RAS_strength			
addr_strength			
DRAM_data_strength			
OEW strength			

Table A.20.2 DRAM Interface configuration  
registers (contd)

#### A.20. ~~F~~ Interface timing (ticks)

In the present invention, the DRAM interface timing is derived from a clock which is running at four times the input clock rate of the device (decoder\_clock). This clock is generated by an on-chip PLL.

For brevity, periods of this high speed clock are referred to as ticks.

### A.20.2 Interface operation

The interface uses of the DRAM fast page mode. Three  
10 different types of access are supported:

- Read
- Write
- Refresh

Each read or write access transfers a burst of between 1  
15 and 64 bytes at a single DRAM page address. Read and write  
transfers are not mixed within a single access. Each  
successive access is treated as a random access to a new  
DRAM page.

### A.20.3 Access structure

20 Each access is composed of two parts:

- Access start
- Data transfer

Each access starts with an access start and is followed by one or more data transfer cycles. There is a read, write and refresh variant of both the access start and the data transfer cycle.

At the end of the last data transfer in an access the interface enters it's default state and remains in this state until a new access is ready to start. If a new access is ready to start when the last access finishes, then the new access will start immediately.

### A.20.3.1 Access start

The access start provides the page address for the read or write transfers and establishes some initial signal

conditions. There are three different access starts:

- Start of read
- Start of write
- Start of refresh

- 5 In each case the timing of  $\overline{\text{RAS}}$  and the row address is controlled by the registers  $\text{RAS\_falling}$  and  $\text{page\_start\_length}$ . The state of  $\overline{\text{OE}}$  and  $\text{DRAM\_data}[31:0]$  is held from the end of the previous data transfer until  $\overline{\text{RAS}}$  falls. The three different access start types are only
- 10 different in how they drive  $\overline{\text{OE}}$  and  $\text{DRAM\_data}[31:0]$  when  $\overline{\text{RAS}}$  falls. See Figure 109.

Num.	Characteristic	Min.	Max.	Unit	Notes
38	$\overline{\text{RAS}}$ precharge period set by register $\text{RAS\_falling}$	4	16	tck	
39	Access start duration set by register $\text{page\_start\_length}$	4	32		
40	$\overline{\text{CAS}}$ precharge length set by register $\text{CAS\_falling}$ .	1	16		
41	Fast page read cycle length set by the register $\text{read\_cycle\_length}$ .	4	16		
42	Fast page write cycle length set by the register $\text{write\_cycle\_length}$ .	4	16		
43	$\overline{\text{WE}}$ falls one tck after $\overline{\text{CAS}}$ .				
44	Refresh cycle length set by the register $\text{refresh\_cycle}$ .	4	16		

**Table A.20.3 Access start parameters**

- a. This value must be less than  $\text{RAS\_falling}$  to ensure  $\overline{\text{CAS}}$  before  $\overline{\text{RAS}}$  refresh occurs.

### A.20.3.2. Data transfer

There are three different types of data transfer cycle:

- Fast page read cycle
- Fast page late write cycle
- Refresh cycle

A start of refresh is only followed by a single refresh cycle. A start of read (or write) can be followed by one or more fast page read (or write) cycles.

At the start of the read cycle CAS is driven high and  
10 the new column address is driven.

A late write cycle is used. ~~WE~~ is driven low one tick after ~~CAS~~. The output data is driven one tick after the address.

As a ~~CAS~~ before ~~RAS~~ refresh cycle is initiated by the  
15 start of refresh cycle, there is no interface signal  
activity during a refresh cycle. The purpose of the  
refresh cycle is to meet the minimum ~~RAS~~ low period  
required by the DRAM.

### A.20.3.3 Interface default state

20       The interface signals enter a default state at the end  
of an access:

- ```
· RAS, CAS and WE high
· data and OE remain in their previous state
· addr remains stable
```

25      A.20.4    Data bus width

The two bit register `DRAM_data_width` allows the width of the DRAM interfaces data path to be configured. This allows the DRAM cost to be minimized when working with small picture formats.

| DRAM_data_width |                                                         |
|-----------------|---------------------------------------------------------|
| 0 <sup>a</sup>  | 8 bit wide data bus on DRAM_data[31:24] <sup>a</sup> .  |
| 1               | 16 bit wide data bus on DRAM_data[31:16] <sup>b</sup> . |
| 2               | 32 bit wide data bus on DRAM_data[31:0].                |

**Table A.20.4 Configuring DRAM\_data\_width**

- a. Default after reset.
- b. Unused signals are held high impedance.

#### **A.20.5 Address bits**

- 5 On-chip, a 24 bit address is generated. How this address is used to form the row and column addresses depends on the width of the data bus and the number of bits selected for the row address. Some configurations do not permit all the internal address bits to be used (and)
- 10 therefore, produce "hidden bits).

The row address is extracted from the middle portion of the address. This maximizes the rate at which the DRAM is naturally refreshed.

##### **A.20.5.1 Low order column address bits**

- 15 The least significant 4 to 6 bits of the column address are used to provide addresses for fast page mode transfers of up to 64 bytes. The number of address bits required to control these transfers will depend on the width of the data bus (see A.20.4).

**A.20.5.2 Row address bits**

The number of bits taken from the middle section of the 24 bit internal address to provide the row address is configured by the register `row_address_bits`.

| <code>row_address_bits</code> | Width of row address |
|-------------------------------|----------------------|
| 0                             | 9 bits               |
| 1                             | 10 bits              |
| 2                             | 11 bits              |

5 **Table A.20.5 Configuring `row_address_bits`**

The width of row address used will depend on the type of DRAM used and whether the MSBs of the row address are decoded off-chip to access multiple banks of DRAM.

10 NOTE: The row address is extracted from the middle of the internal address. If some bits of the row address are decoded to select banks of DRAM, then all possible values of these "bank select bits" must select a bank of DRAM. Otherwise, holes will be left in the address space.

00000000 00000000 00000000 00000000



| row_address_bits | row address bits | bank select     | DRAM depth |
|------------------|------------------|-----------------|------------|
| 0                | DRAM_addr[8:0]   |                 | 256k       |
| 1                | DRAM_addr[8:0]   | DRAM_addr[9]    | 256k       |
|                  | DRAM_addr[9:0]   |                 | 512k       |
|                  | DRAM_addr[9:0]   |                 | 1024k      |
| 2                | DRAM_addr[8:0]   | DRAM_addr[10:9] | 256k       |
|                  | DRAM_addr[9:0]   | DRAM_addr[10]   | 512k       |
|                  | DRAM_addr[9:0]   | DRAM_addr[10]   | 1024k      |
|                  | DRAM_addr[10:0]  |                 | 2048k      |
|                  | DRAM_addr[10:0]  |                 | 4096k      |

Table A.20.6 Selecting a value for row\_address\_bits

#### A.20.6 DRAM Interface enable

There are two ways to make all the output signals on the DRAM interface become high impedance. The DRAM\_enable register and the DRAM\_enable signal. Both the register and the signal must be at a logic 1 for the DRAM interface to operate. If either is low, then the interface is taken to high impedance and data transfers through the interface are halted.

The ability to take the DRAM interface to high impedance is provided in order to allow other devices to test or to use the DRAM controlled by the Spatial Decoder (or the Temporal Decoder) when the Spatial Decoder (or the Temporal

Decoder) is not in use. It is not intended to allow other devices to share the memory during normal operation.

#### A.20.7 Refresh

Unless disabled by writing to the register, no\_refresh, the DRAM interface will automatically refresh the DRAM using a CAS before RAS refresh cycle at an interval determined by the register refresh\_interval.

The value in refresh\_interval specifies the interval between refresh cycles in periods of 16 decoder\_clock cycles. Values in the range 1 to 255 can be configured. The value 0 is automatically loaded after reset and forces the DRAM interface to continuously execute refresh cycles (once enabled) until a valid refresh interval is configured. It is recommended that refresh\_interval should be configured only once after each reset.

#### A.20.8 Signal strengths

The drive strength of the outputs of the DRAM interface can be configured by the user using the 3 bit registers, CAS\_strength, RAS\_strength, addr\_strength, DRAM\_data\_strength, OEWE\_strength. The MSB of this 3 bit value selects either a fast or slow edge rate. The two less significant bits configure the output for different load capacitances.

The default strength after reset is 6, configuring the outputs to take approximately 10 ns to drive signal between GND and  $V_{DD}$  if loaded with 12pF.

00000000 00000000 00000000 00000000

| strength value | Drive characteristics          |
|----------------|--------------------------------|
| 0              | Approx. 4 ns/V into 6 pF load  |
| 1              | Approx. 4 ns/V into 12 pF load |
| 2              | Approx. 4 ns/V into 24 pF load |
| 3              | Approx. 4 ns/V into 48 pF load |
| 4              | Approx. 2 ns/V into 6 pF load  |
| 5              | Approx. 2 ns/V into 12 pF load |

| strength value | Drive characteristics          |
|----------------|--------------------------------|
| 6*             | Approx. 2 ns/V into 24 pF load |
| 7              | Approx. 2 ns/V into 48 pF load |

**Table A.20.7 Output strength configurations**

**a. Default after reset**

When an output is configured approximately for the load it is driving, it will meet the AC electrical characteristics specified in Tables A.20.11 to Table A.20.12. When appropriately configured each output is approximately matched to its load and, therefore, minimal overshoot will occur after a signal transition.

**A.20.9 After reset**

After reset, the DRAM interface configuration registers are all reset to their default values. Most significant of these default configurations are:

- The DRAM interface is disabled and allowed to go high impedance.

- The refresh interval is configured to the special value 0 which means execute refresh cycle continuously after the interface is re-enabled.

- The DRAM interface is set to its slowest configuration.

Most DRAMs require a "pause" of between 100 $\mu$ s and 500 $\mu$ s

Immediately after reset, the DRAM interface is inactive until both the DRAM\_enable signal and the DRAM\_enable register are set. When these have been set, the DRAM interface will execute refresh cycles (approximately every 400 ns, depending upon the clock frequency used) until the DRAM interface is configured.

15 While reset is asserted, the DRAM interface is unable to refresh the DRAM. However, the reset time required by the decoder chips is sufficiently short so that it should be possible to reset them and to then re-enable the DRAM interface before the DRAM contents decay. This may be required during debugging.

| Symbol          | Parameter                      | Min.      | Max.                  | Units |
|-----------------|--------------------------------|-----------|-----------------------|-------|
| V <sub>DD</sub> | Supply voltage relative to GND | -0.5      | 6.5                   | V     |
| V <sub>IN</sub> | Input voltage on any pin       | GND - 0.5 | V <sub>DD</sub> + 0.5 | V     |
| T <sub>A</sub>  | Operating temperature          | -40       | +85                   | °C    |
| T <sub>S</sub>  | Storage temperature            | -55       | +150                  | °C    |

20

| Symbol          | Parameter                      | Min.      | Max.                  | Units |
|-----------------|--------------------------------|-----------|-----------------------|-------|
| V <sub>DD</sub> | Supply voltage relative to GND | 4.75      | 5.25                  | V     |
| GND             | Ground                         | 0         | 0                     | V     |
| V <sub>IH</sub> | Input logic '1' voltage        | 2.0       | V <sub>DD</sub> - 0.5 | V     |
| V <sub>IL</sub> | Input logic '0' voltage        | GND - 0.5 | 0.8                   | V     |
| T <sub>A</sub>  | Operating temperature          | 0         | 70                    | °C*   |

Table A.20.9 DC Operating conditions

a. With TBA linear ft/min transverse airflow

| Symbol   | Parameter                        | Min.      | Max. | Units          |
|----------|----------------------------------|-----------|------|----------------|
| $V_{OL}$ | Output logic '0' voltage         |           | 0.4  | V <sup>a</sup> |
| $V_{OH}$ | Output logic '1' voltage         | 2.8       |      | V              |
| $I_O$    | Output current                   | $\pm 100$ |      | $\mu A^b$      |
| $I_{OZ}$ | Output off state leakage current | $\pm 20$  |      | $\mu A$        |
| $I_{IZ}$ | Input leakage current            | $\pm 10$  |      | $\mu A$        |
| $I_{OO}$ | RMS power supply current         |           | 500  | mA             |
| $C_{IN}$ | Input capacitance                |           | 5    | pF             |

| Symbol    | Parameter               | Min. | Max. | Units |
|-----------|-------------------------|------|------|-------|
| $C_{OUT}$ | Output / IO capacitance |      | 5    | pF    |

**Table A.20.10 DC Electrical characteristics (contd)**

Table A.20.10 DC Electrical characteristics

- a. AC parameters are specified using  $V_{OLmax}=0.8V$  as the measurement level.
- b. This is the steady state drive capability of the interface. Transient currents may be much greater.

## A.20.10.1 AC characteristics

| Num. | Parameter                                          | Min. | Max. | Unit | Note * |
|------|----------------------------------------------------|------|------|------|--------|
| 45   | Cycle time e.g. tPC                                | -2   | -2   | ns   |        |
| 46   | Cycle time e.g. tRC                                | -2   | -2   | ns   |        |
| 47   | High pulse e.g. tRP, tCP, tCPN                     | -5   | -2   | ns   |        |
| 48   | Low pulse e.g. tRAS, tCAS, tCAC, tWP, tRASP, tRASC | -11  | -2   | ns   |        |
| 49   | Cycle time e.g. tACP/tCPA                          | -8   | -2   | ns   |        |

Table A.20.11 Differences from nominal values for a strobe

Table A.20.11 Differences from nominal values for a strobe

- a. The driver strength of the signal must be configured appropriately for its load

| Num. | Parameter                                                                                                                                                                                               | Min. | Max. | Unit | Note * |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|--------|
| 50   | Strobe to strobe delay e.g. tRCD, tCSR                                                                                                                                                                  | -3   | -3   | ns   |        |
| 51   | Low hold time e.g. tRSH, tCSH, tRWL, tCWL, tRAC, tOAC/OE, tCHR                                                                                                                                          | -13  | -3   | ns   |        |
| 52   | Strobe to strobe precharge e.g. tCRP, tRCS, tRCH, tRRH, tRPC                                                                                                                                            | -9   | -3   | ns   |        |
|      | $\overline{\text{CAS}}$ precharge pulse between any two $\overline{\text{CAS}}$ signals on wide DRAMs e.g. tCP, or between $\overline{\text{RAS}}$ rising and $\overline{\text{CAS}}$ falling e.g. tRPC | -5   | -2   | ns   |        |

Table A.20.12 Differences from nominal values between two strobes

Table A.20.12 Differences from nominal values between two strobes

| Num. | Parameter                                    | Min. | Max. | Unit | Note * |
|------|----------------------------------------------|------|------|------|--------|
| 53   | Precharge before disable e.g. (RHCP/<br>CPRH | -12  | +3   | ns   |        |

**Table A.20.12 Differences from nominal  
values between two strobes (contd)**

- a. The driver strength of the two signals must be configured appropriately for their loads

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### B.1.1 Overview

Typically, start codes are 24, 16 and 8 bits wide for MPEG, H.261, and JPEG, respectively. The Start Code Detector takes the incoming data in bytes, either from the Microprocessor Interface (upi) or a token/byte port and shifts it through three shift registers. The first register is an 8 bit parallel in serial out, the second register is of programmable length (16 or 24 bits) and is where the start codes are detected, and the third register is 15 bits wide and is used to reformat the data into 15 bit tokens. There are also two "tag" Shift Registers (SR) running parallel with the second and third SRs. These contain tags to indicate whether or not the associated bit in the data SR is good. Incoming bytes that are not part of a DATA Token and are unrecognized by the SCD, are allowed to bypass the shift registers and are output when all three shift registers are flushed (empty) and the contents output successfully. Recognized non-data tokens are used to configure the SCD, spring traps, or set flags. They also bypass the shift registers and are output unchanged.

The hardware for the Start Code Detector consists of 10 state machines.

The input circuit has three modes of operation: token, byte and microprocessor interface. These modes allow data





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```

    state = LOOKING;
break;
case (GETVALUE);
    if (input == 0xff)
    {
        state = GETVALUE; /*Overlapping markers*/
        remove;
    }
    else if (input == 0x00)
    {
        state = LOOKING; /*Wasn't a marker*/
        insert(0xff); /*Put the 0xff back*/
    }
else
{
    command = BYPASS; /*override command*/
    if(lc) /* Does the marker have a length count*/
        state = GETLC0;
    else
        state = LOOKING;
break;
case (GETLC0):
    loadlc0; /*Load the top length count byte*/
    state = GETLC1;
    remove;
break;
case (GETLC1)
    loadlc1;
    remove;
    state = DECLC;
break;
case (DECLC):
    lcnt = lcnt - 2

```

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```

— state = CHECKLC;
break;
case (CHECKLC):
    if (lcnt == 0)
        state = LOOKING; /*No more to do*/
    else if (lcnt < 0)
        state = LOOKING; /*generate Illegal_Length_Error*/
    else
        state = COUNT;
break;
case (COUNT):
    decrement length count until 1
    if (lc <= 1)
        state = LOOKING;
}

```

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#### B.1.2.4 Input Shifter (scinshift.sch, scinshm.M)

The basic operation of this block is quite simple. This block takes a byte of data from the input circuit, loads the shift register and shifts it out. However, it also obeys the commands from the input decoder and handles the transitions to and from bypass mode (flushing the other SRs): On receiving a BYPASS command, the associated byte is not loaded into the shift register. Instead "rubbish" (tag = 1) is shifted out to force any data held in the other shift registers to the output. The block then waits for a "flushed" signal indicating that this "rubbish" has appeared at the token reconstructor. The input byte is then passed directly to the token reconstructor.

#### B.1.2.5 Start Code Detector (scdetect.sch, scdetm.M)

This block includes two shift registers which are programmable to 16 or 24 bits, start code detection logic and "valid contents" detection logic. MPEG start codes require the full 24 bits, whereas H.261 requires only 16.

In the present invention, the first SR is for data and the second carries tags which indicate whether the bits in the data SR are valid - there are no gaps or stalls (in the two-wire interface sense) in the SRs, but the bits they contain can be invalid (rubbish) whilst they are being flushed. On detection of a start code, the tag shift register bits are set in order to invalidate the contents of the detector SR.

A start code cannot be detected unless the SR contents are all valid. Non byte-aligned start codes are detected and may be flagged. Moreover, when a start code is detected, it cannot be definitely flagged until an overlapping start code has been checked for. To accomplish this function, the "value" of the detected start code (the byte following it) is shifted right through scinshift, scdetect and into scoshift. Having arrived at scoshift without the detection of another start code, it is overlapping start codes have been eliminated and it is flagged as a valid start code.

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generated. In this case, the first value is discarded and the system then waits for the second value. This value can also be overlapped, thus causing the same procedure to be repeated until a non-overlapped start code is found.

5 **B.1.2.6.4 Tidying up after a start code**

Having detected and output a good start code, a new DATA header is generated when data (not rubbish) starts arriving.

10 **B.1.2.7 Data stream reconstructor (sctokrec.sch, sctokrem.M)**

The Data Stream reconstructor has two-wire interface inputs: one from scinshift for bypassed tokens, and one from scoshift for packed data and start codes. Switching between the two sources is only allowed when the current token (from either source) has been completed (low extension bit arrived).

**B.1.2.8 Start value to start number conversion (scdromhw.sch, schrom.M)**

20 The process of converting start values into tokens is done in two stages. This block deals mainly with coding standard dependent issues reducing the 520 odd potential codes down to 16 coding standard independent indices.

As mentioned earlier, start values (including JPEG ones) are distinguished from all other data by a flag (value\_not\_token). If v\_not\_t is high, this block converts the 4 or 8 bit value, depending on the CODING\_STANDARD, into a 4 bit start\_number which is independent of the standard, and flags any unrecognized start codes.

The start numbers are as follows:

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

Table B.1.2 Start Code numbers (indices)

| Start/Marker Code                                          | Index (start_number) | Resulting Token |
|------------------------------------------------------------|----------------------|-----------------|
| not_a_start_code                                           | 0                    | ..              |
| sequence_start_code                                        | 1                    | SEQUENCE_START  |
| group_start_code                                           | 2                    | GROUP_START     |
| picture_start_code                                         | 3                    | PICTURE_START   |
| slice_start_code                                           | 4                    | SLICE_START     |
| user_data_start_code                                       | 5                    | USER_DATA       |
| extension_start_code                                       | 6                    | EXTENSION_DATA  |
| sequence_end_code                                          | 7                    | SEQUENCE_END    |
| JPEG Markers                                               |                      |                 |
| DHT                                                        | 8                    | DHT             |
| DQT                                                        | 9                    | DQT             |
| DNL                                                        | 10                   | DNL             |
| DRI                                                        | 11                   | DRI             |
| JPEG markers that can be mapped onto tokens for MPEG/H.261 |                      |                 |
| SOS                                                        | picture_start_code   | PICTURE_START   |
| SOI                                                        | sequence_start_code  | SEQUENCE_START  |

Table B.1.2 Start Code numbers (indices)

| Start/Marker Code                                                      | Index (start_number) | Resulting Token |
|------------------------------------------------------------------------|----------------------|-----------------|
| EOI                                                                    | sequence_end_code    | SEQUENCE_END    |
| SOF0                                                                   | group_start_code     | GROUP_START     |
| JPEG markers that generate extrn or user data                          |                      |                 |
| JPG                                                                    | extension_start_code | EXTENSION_DATA  |
| JPGn                                                                   | extension_start_code | EXTENSION_DATA  |
| APPn                                                                   | user_data_start_code | USER_DATA       |
| COM                                                                    | user_data_start_code | USER_DATA       |
| NOTE: All unrecognised JPEG markers generate an extrn_start_code index |                      |                 |

#### B.1.2.9 Start number to token conversion (sconvert.sch, sconvrm.M)

The second stage of the conversion is where the above start numbers (or indices) are converted into tokens. This block also handles token extensions where appropriate, discarding of extension and user data, and search modes.





```

switch (input_data)
case (FLUSH)
    1. if (in_picture)
        output = PICTURE_END
    2. output = FLUSH
    3. if (in_picture & stop_after_picture)
        sap_error = HIGH
        in_picture = FALSE;
    4. in_picture = FALSE;
break
case (SEQUENCE_START)
    1. if (in_picture)
        output = PICTURE_END
    2. if (in_picture & stop_after_picture)
        2a. output = FLUSH
        2b. sap_error = HIGH
        in_picture = FALSE
    3. output = CODING_STANDARD
    4. output = standard
    5. output = SEQUENCE_START
    6. in_picture = FALSE;
break
case (SEQUENCE_END) case (GROUP_START):
    1. if (in_picture)
        output = PICTURE_END
    2. if (in_picture & stop_after_picture)
        2a. output = FLUSH
        2b. sap_error = HIGH
        in_picture = FALSE
    3. output = SEQUENCE_END or GROUP_START
    4. in_picture = FALSE;
break
case (PICTURE_END)

```

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1. output = PICTURE\_END  
2. if (stop\_after\_picture)  
    2a. output = FLUSH  
    2b. sap\_error = HIGH  
3. in\_picture = FALSE  
break  
case (PICTURE\_START)  
1. if (in\_picture)  
    output = PICTURE\_END  
2. if (in\_picture & stop\_after\_picture)  
    2a. output = FLUSH  
    2b. sap\_error = HIGH  
3. if (insert\_sequence\_start)  
    3a. output = CODING\_STANDARD  
    3b. output = standard  
    3c. output = SEQUENCE\_START  
    insert\_sequence\_start = FALSE  
4. output = PICTURE\_START  
    in\_picture = TRUE  
break  
default: Just pass it through

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## SECTION B.2 Huffman Decoder and Parser

### B.2.1 Introduction

This section describes the Huffman Decoder and Parser circuitry in accordance with the present invention.

5     Figure 118 shows a high level block diagram of the Huffman Decoder and Parser. Many signals and buses are omitted from this diagram in the interests of clarity, in particular, there are several places where data is fed backwards (within the large loop that is shown).

10     In essence, the Huffman Decoder and Parser of the present invention consist of a number of dedicated processing blocks (shown along the bottom of the diagram) which are controlled by a programmable state machine.

15     Data is received from the Coded Data Buffer by the "Inshift" block. At this point, there are essentially two types of information which will be encountered: Coded data which is carried by DATA Tokens and start codes which have already been replaced by their respective Tokens by the Start Code Detector. It is possible that other Tokens will  
20     be encountered but all Tokens (other than the DATA Tokens) are treated in the same way. Tokens (start codes) are treated as a special case as the vast majority of the data will still be encoded (in H.261, JPEG or MPEG).

25     In the present invention, all data which is carried by the DATA Tokens is transferred to the Huffman Decoder in a serial form (bit-by-bit). This data, of course, includes many fields which are not Huffman coded, but are fixed length coded. Nevertheless, this data is still passed to the Huffman Decoder serially. In the case of Huffman  
30     encoded data, the Huffman Decoder only performs the first stage of decoding in which the actual Huffman code is replaced by an index number. If there are N distinct Huffman codes in the particular code table which is being decoded, then this "Huffman Index" lies in the range 0 to  
35     N-1. Furthermore, the Huffman Decoder has a "no op", i.e., "no operation" mode, which allows it to pass along data or token information to a subsequent stage without any

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processing by the Huffman Decoder.

The Index to Data Unit is a relatively simple block of circuitry which performs table look-up operations. It draws its name from the second stage of the Huffman decoding process in which the index number obtained in the Huffman Decoder is converted into the actual decoded data by a simple table look-up. The Index to Data Unit cooperates with the Huffman Decoder to act as a single logical unit.

The ALU is the next block and is provided to implement other transformations on the decoded data. While the Index to Data Unit is suitable for relatively arbitrary mappings, the ALU may be used where arithmetic is more appropriate. The ALU includes a register file which it can manipulate to implement various parts of the decoding algorithms. In particular, the registers which hold vector predictions and DC predictions are included in this block. The ALU is based around a simple adder with operand selection logic. It also includes dedicated circuitry for sign-extension type operations. It is likely that a shift operation will be implemented, but this will be performed in a serial manner; there will be no barrel shifter.

The Token Formatter, in accordance with the present invention, is the last block in the Video Parser and has the task of finally assembling decoded data into Tokens which can be passed onto the rest of the decoder. At this point, there are as many Tokens as will ever be used by the decoder for this particular picture.

The Parser State Machine, which is 18 bits wide and has been adopted for use with a two-wire interface has the task of coordinating the operation of the other blocks. In essence, it is a very simple state machine and it produces a very wide "micro-code" control word which is passed to the other blocks. Figure 118 shows that the instruction word is passed from block-to-block by the side of the data. This is, indeed, the case and it is important to understand that transfers between the different blocks are controlled

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by two-wire interfaces.

In the present invention, there is a two-wire interface between each of the blocks in the Video Parser. Furthermore, the Huffman Decoder works with both serial,  
 5 data, the inshifter inputs data one bit at a time, and with control tokens. Accordingly, there are two modes of operation. If data is coming into the Huffman Decoder via a DATA Token, then it passes through the shifter one bit at a time. Again, there is a two-wire interface between the  
 10 inshifter and the Huffman Decoder. Other tokens, however, are not shifted in one bit at a time (serial) but rather in the header of the token. If a DATA token is input, then the header containing the address information is deleted and the data following the address is shifted in one bit at  
 15 a time. If it is not a DATA Token, then the entire token, header and all, is presented to the Huffman Decoder all at once.

In the present invention, it is important to understand that the two-wire interface for the Video Parser is unusual  
 20 in that it has two valid lines. One line is valid serially and one line is valid tokenly. Furthermore, both lines may not be asserted at the same time. One or the other may be asserted or if no valid data exists, then neither may be asserted although there are two valid lines, it should be  
 25 recognized that there is only a single accept wire in the other direction. However, this is not a problem. The Huffman Decoder knows whether it wants serial data or token information depending on what needs to be done next based upon the current syntax. Hence, the valid and accept  
 30 signals are set accordingly and an Accept is sent from the Huffman Decoder to the inshifter. If the proper data or token is there, then the inshifter sends a valid signal.

For example, a typical instruction might decode a Huffman code, transform it in the Index to Data Unit, modify that  
 35 result in the ALU and then this result is formed into a Token word. A single microcode instruction word is produced which contains all of the information to do this.

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

The command is passed directly to the Huffman Decoder which  
 requests data bits one-by-one from the "Inshift" block  
 until it has decoded a complete symbol. Control Tokens are  
 input in parallel. Once this occurs, the decoded index  
 5 value is passed along with the original microcode word to  
 the Index to Data Unit. Note that the Huffman Decoder will  
 require several cycles to perform this operation and,  
 indeed, the number of cycles is actually determined by the  
 data which is decoded. The Index to Data Unit will then  
 10 map this value using a table which is identified in the  
 microcode instruction word. This value is again passed  
 onto the next block, the ALU, along with the original  
 microcode word. Once the ALU has completed the appropriate  
 operation (the number of cycles may again be data  
 15 dependant) it passes the appropriate data onto the Token  
 Formatting block along with the microcode word which  
 controls the way in which the Token word is formed.

The ALU has a number of status wires or "condition codes"  
 which are passed back to the Parser State Machine. This  
 20 allows the State Machine to execute conditional jump  
 instructions. In fact, all instructions are conditional  
 jump instructions; one of the conditions that may be  
 selected is hard-wired to the value "False". By selecting  
 this condition, a "no jump" instruction may be constructed.

25 In accordance with the present invention, the Token  
 Formatter has two inputs: a data field from the ALU and/or  
 a constant field coming from the Parser State Machine. In  
 addition, there is an instruction that tells the Token  
 Formatter how many bits to take from one source and then to  
 30 fill in with the remaining bits from the other for a total  
 of 8 bits. For example, HORIZONTAL\_SIZE has an 8 bit field  
 that is an invariant address identifying it as a  
 HORIZONTAL\_SIZE Token. In this case, the 8 bits come from  
 the constant field and no data comes from the ALU. If,  
 35 however, it is a DATA Token, then you would likely have 6  
 bits from the constant field and two lower bits indicating  
 the color components from the ALU. Accordingly, the Token

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Formatter takes this information and puts it into a token for use by the rest of the system. Note that the number of bits from each source in the above examples are merely for illustration purposes and one of ordinary skill in the art will appreciate that the number of bits from either source can vary.

The ALU includes a bank of counters that are used to count through the structure of the picture. The dimensions of the picture are programmed into registers associated with the counters that appear to the "microprogrammer" as part of the register bank. Several of the condition codes are outputs from this counter bank which allows conditional jumps based on "start of picture", "start of macroblock" and the like.

Note that the Parser State Machine is also referred to as the "Demultiplex State Machine". Both terms are used in this document.

#### Input Shifter

In the present invention, the Input Shifter is a very simple piece of circuitry consisting of a two pipeline stage datapath ("hfidp") and controlling Zcells ("hfi").

In the first pipeline stage, Token decoding takes place. At this stage, only the DATA token is recognized. Data contained in a DATA token is shifted one bit at a time into the Huffman Decoder. The second pipeline stage is the shift register. In the very last word of a DATA token, special coding takes place such that it is possible to transmit an arbitrary number of bits through the coded data buffer. The following are all possible patterns in the last data word.



| E | D | C | B | A | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | No. of Bits |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|-------------|
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | None        |
| x | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1           |
| x | x | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2           |
| x | x | x | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3           |
| x | x | x | x | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4           |
| x | x | x | x | x | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 5           |
| x | x | x | x | x | x | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 6           |
| x | x | x | x | x | x | x | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7           |
| x | x | x | x | x | x | x | x | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 8           |
| x | x | x | x | x | x | x | x | x | 0 | 1 | 1 | 1 | 1 | 1 | 9           |
| x | x | x | x | x | x | x | x | x | x | 0 | 1 | 1 | 1 | 1 | 10          |
| x | x | x | x | x | x | x | x | x | x | x | 0 | 1 | 1 | 1 | 11          |
| x | x | x | x | x | x | x | x | x | x | x | x | 0 | 1 | 1 | 12          |
| x | x | x | x | x | x | x | x | x | x | x | x | x | 0 | 1 | 13          |
| x | x | x | x | x | x | x | x | x | x | x | x | x | x | 0 | 14          |

Table B.2.1 Possible Patterns in the Last Data Word

As the data bits are shifted left, one by one, in the shift register, the bit pattern "0 followed by all ones" is looked for (padding). This indicates that the remaining bits in the shift register are not valid and they are discarded. Note that this action only takes place in the last word of a DATA Token.

As described previously, all other Tokens are passed to the Huffman Decoder in parallel. They are still loaded into the second pipeline stage, but no shifting takes place. Note that the DATA header is discarded and is not passed to the Huffman at all. Two "valid" wires (out\_valid and serial\_valid) are provided. Only one is asserted at a given time and it indicates what type of data is being presented at that moment.

### B.2.2 Huffman Decoder

The Huffman Decoder has a number of modes of operation. The most obvious is that it can decode Huffman Codes, turning them into a Huffman Index Number. In addition, it  
5 can decode fixed length codes of a length (in bits) determined by the instruction word. The Huffman Decoder can also accept Tokens from the Inshift block.

The Huffman Decode includes a very small state machine. This is used when decoding block-level information. This  
10 is because it takes too long for the Parser State Machine to make decisions (since it must wait for data to flow through the Index to Data Unit and the ALU before it can make a decision about that data and issue a new command). When this State Machine is used, the Huffman Decoder itself  
15 issues commands to the Index to Data Unit and ALU. The Huffman Decoder State Machine cannot control all of the microcode instruction bits and, therefore, it cannot issue the full range of commands to the other blocks.

#### B.2.2.1 Theory of Operation

20 When decoding Huffman codes, the Huffman Decoder of the present invention uses an arithmetic procedure to decode the incoming code into a Huffman Index Number. This number lies between 0 and N-1 (for a code table that has N entries). Bits are accepted one by one from the Input  
25 shifter.

In order to control the operation of the machine, a number of tables are required. These specify for each possible number of bits in a code (1 to 16 bits) how many codes there are of that length. As expected, this  
30 information is typically not sufficient to specify a general Huffman code. However, in MPEG, H.261 and JPEG, the Huffman codes are chosen such that this information alone can specify the Huffman Code table. There is unfortunately just one exception to this; the Tcoefficient  
35 table from H.261 which is also used in MPEG. This requires an additional table that is described elsewhere (the exception was deliberately introduced in H.261 to avoid

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start code emulation).

It is important to realize that the tables used by this Huffman Decoder are precisely the same as those transmitted in JPEG. This allows these tables to be used directly while other designs of Huffman decoders would have required the generation of internal tables from the transmitted ones. This would have required extra storage and extra processing to do the conversion. Since the tables in MPEG and H.261 (with the exception noted above) can be described in the same way, a multi-standard decoder becomes practical.

The following fragment of "C" illustrates the decoding process;

```

15  int total = 0;
    int s = 0;
    int bit = 0;
    unsigned long code = 0;
    int index = 0;

    while (index >= total)
20  {
    if (bit >= max_bits)
        fail("huff_decode: ran off end of huff table\n");

        code = (code << 1) | next_bit0;

        index = code - s + total;
25  total += codes_per_bit(bit);
        s = (s + codes_per_bit(bit)) << 1;

        bit++;
    }

```

The process generally, is directly mapped into the silicon implementation although advantage is taken of the fact that certain intermediate values can be calculated in clock phases before they are required.

From the code fragment we see that;

$$\text{EQ 1. } \text{total}_{n+1} = \text{total}_n + \text{cpb}_n$$

$$\text{EQ 2. } 's_{n+1} = 2('s_n + \text{cpb}_n)$$

$$\text{EQ 3. } \text{code}_{n+1} = 2\text{code}_n + \text{bit}_n$$

$$\text{EQ 4. } \text{index}_{n+1} = 2\text{code}_n + \text{bit}_n + \text{total}_n - 's_n$$

Unfortunately in the hardware it proved easier to use a modified set of equations in which a variable "shifted" is used in place of the variable "s". In this case;

In the hardware, however, it proved easier to use a modified set of equations in which a variable "shifted" is used in place of the variable "s". In this case;

$$\text{EQ 5. } \text{shifted}_{n+1} = 2\text{shifted}_n + \text{cpb}_n$$

It turns out that:

$$\text{EQ 6. } i_n = 2\text{shifted}_n$$

5 and so substituting this back into Equation 4 we see that:

$$\text{EQ 7. } \text{index}_{n+1} = 2(\text{code}_n - \text{shifted}_n) + \text{total}_n + \text{bit}_n$$

In addition to calculating successive values of "index", it is necessary to know when the calculation is completed. From the "C" code fragment we see that we are done when:

$$\text{EQ 8. } \text{index}_{n+1} < \text{total}_{n+1}$$

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Substituting from Equation 7 and Equation 1 we see that we are done when:

$$\text{EQ 9. } 2(\text{code}_n - \text{shifted}_n) + \text{bit}_n - \text{cpb}_n < 0$$

In the hardware implementation of the present invention, the common term in Equation 7 and Equation 9,  $(\text{code}_n - \text{shifted}_n)$  is calculated one phase before the remainder of these equations are evaluated to give the final result and the information that the calculation is "done".

One word of warning. In various pieces of "C" code, notably the behavioral compiled code Huffman Decoder and the sm4code projects, the "C" fragment is used almost directly, but the variable "s" is actually called "shifted". Thus, there are two different variables called "shifted". One in the "C" code and the other in the hardware implementation. These two variables differ by a factor of two.

#### B.2.2.1.1 Inverting the Data Bits

There is one other piece of information required to correctly decode the Huffman codes. This is the polarity of the coded data. It turns out that H.261 and JPEG use opposite conventions. This reflects itself in the fact that the start codes in H.261 are zero bits whilst the marker bytes in JPEG are one bits.

In order to deal with both conventions, it is necessary to invert the coded data bits as they are read into the Huffman Decoder in order to decode H.261 style Huffman codes. This is done in the obvious manner using an exclusive OR gate. Note that the inversion is only performed for Huffman codes, as when decoding fixed length codes, the data is not inverted.

MPEG uses a mix of the two conventions. In those aspects inherited from H.261, the H.261 convention is used. In

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(no new codes are introduced or old codes omitted).

Furthermore, a unique implementation is used for the very first coefficient in a block. In this case, it is impossible for an end-of-block code to occur and, therefore, the table is modified so that the most commonly occurring symbol can use the code that would otherwise be interpreted as end-of-block. This may save one bit. It turns out that with the architecture for decoding, in accordance with the present invention, this is easily accommodated. In short, for the first bit of the first coefficient the decoding is deemed "done" if "index" has the value zero. Furthermore, after decoding only a single bit there are only two possible values for "index", zero and one, it is only necessary to test one bit.

#### 15 B.2.2.1.3 Register and Adder Size

The Huffman Decoder of the present invention can deal with Huffman codes that may be as long as 16 bits. However, the decoding machine is only eight bits wide. This is possible because we know that the largest possible value of the decoded Huffman Index number is 255. In fact, this could only happen in extended JPEG and, in the current application, the limit is somewhat lower (but larger than 128, so 7 bits will not suffice).

It turns out that for all legal Huffman codes, not only the final value of "index", but all intermediate values lie in the range 0 to 255. However, for an illegal code, i.e., an attempt to decode a code that is not in the current code table (probably due to a data error) the index value may exceed 255. Since we are using an eight bit machine, it is possible that at the end of decoding, the final value of "index" does not exceed 255 because the more significant bits that tell us an error has occurred have been discarded. For this reason, if at any time during decoding the index value exceeds 255 (i.e., carry out of the adder that forms index) an error occurs and decoding is abandoned.

Twelve bits of "code" are preserved. This is not necessary for decoding Huffman codes where an eight bit register would have been sufficient. These upper bits are required for fixed length codes where up to twelve bits may be read.

#### **B.2.2.1.4 Operation for Fixed Length Codes**

For fixed length codes, the "codes per bit" value is forced to zero. This means that "total" and "shifted" remain at zero throughout the operation and "index" is, therefore, the same as code. In fact, the adders and the like only allow an eight bit value to be produced for "index". Because of this, the upper bits of the output word are taken directly from the "code" register when decoding fixed length codes. When decoding Huffman codes these upper bits are forced to zero.

The fact that sufficient bits have been read from the input is calculated in the obvious manner. A comparator compares the desired number of bits with the "bit" counter.

#### **B.2.2.2 Decoding Coefficient Data**

The Parser State Machine, in accordance with the present invention, is generally only used for fairly high-level decoding. The very lowest level decoding within an eight-by-eight block of data is not directly handled by this state machine. The Parser State Machine gives a command to the Huffman Decoder of the form "decode a block". The Huffman Decoder, Index to Data Unit and ALU work together under the control of a dedicated state machine (essentially in the Huffman Decoder). This arrangement allows very high performance decoding of entropy coded coefficient data. There are also other feedback paths operational in this mode of operation. For instance, in JPEG decoding where the VLCs are decoded to provide SIZE and RUN information, the SIZE information is fed back directly from the output of the Index to Data Unit to the Huffman Decoder to instruct the Huffman Decoder how many FLC bits to read. In addition, there are several accelerators implemented. For instance, using the same example all VLC values which yield



a SIZE of zero are explicitly trapped by looking at the Huffman Index Value before the Index to Data stage. This means that in the case of non-zero SIZE values, the Huffman Decoder can proceed to read one FLC bit BEFORE the actual value of SIZE is known. This means that no clock cycles are wasted because this reading of the first FLC bit overlaps the single clock cycle required to perform the table look-up in the Index to Data Unit.

#### B.2.2.2.1 MPEG and H.261 AC Coefficient Data

Figure 127 shows the way in which AC Coefficients are decoded in MPEG and H.261. A flow chart detailing the operation of the Huffman Decoder is given in Figure 119.

The process starts by reading a VLC code. In the normal course of events, the Huffman index is mapped directly into values representing the six bit RUN and the absolute value of the coefficient. A one bit FLC is then read giving the sign of the coefficient. The ALU assembles the absolute value of the coefficient with this sign bit to provide the final value of the coefficient.

Note that the data format at this point is sign-magnitude and, therefore, there is little difficulty in this operation. The RUN value is passed on an auxiliary bus of six bits while the coefficients value (LEVEL) is passed on the normal data bus.

Two special cases exist and these are trapped by looking at the value of the decoded index before the Index to Data operation. These are End of Block (EOB) and Escape coded data. In the case of EOB, the fact that this occurred is passed along through the Index to Data Unit and the ALU blocks so that the Token Formatter can correctly close the open DATA Token.

Escape coded data is more complicated. First six bits of RUN are read and these are passed directly through the Index to Data Unit and are stored in the ALU. Then, one bit of FLC is read. This is the most significant bit of the eight bits of escape that are described in MPEG and H.261 and it gives the sign of the level. The sign is

00000000000000000000000000000000

explicitly read in this implementation because it is necessary to send different commands to the ALU for negative values versus positive values. This allows the ALU to convert the twos complement value in the bit stream into sign magnitude. In either case, the remaining seven bits of FLC are then read. If this has the value zero, then a further eight bits must be read.

In the present invention, the Huffman Decoder's internal state machine is responsible for generating commands to control itself and to also control the Index to Data Unit, the ALU and the Token Formatter. As shown in Figure 124, the Huffman Decoder's instruction comes from one of three sources, the Parser State Machine, the Huffman State Machine or an instruction stored in a register that has previously been received from the Parser State Machine. Essentially, the original instruction from the Parser State Machine (that causes the Huffman State Machine to take over control and read coefficients) is retained in a register, i.e., each time a new VLC is required, it is used. All the other instructions for the decoding are supplied by the Huffman State Machine.

#### **B.2.2.2.2 MPEG DC Coefficient Data**

This is handled in the same way as JPEG DC Coefficient Data. The same (loadable) tables are used and it is the responsibility of the controlling microprocessor to ensure that their contents are correct. The only real difference from the MPEG standard is that the predictors are reset to zero (like in JPEG) the correction for this being made in the Inverse Quantizer.

#### **B.2.2.2.3 JPEG Coefficient Data**

Figure 120 is a block diagram illustrating the hardware, in accordance with the present invention, for decoding JPEG AC Coefficients. Since the process for DC Coefficients is essentially a simplification of the JPEG process, the diagram serves for both AC and DC Coefficients. The only real addition to the previous diagram for the MPEG AC coefficients is that the "SSSS"

field is fed back and may be used as part of the Huffman Decoder command to specify the number of FLC bits to be read. The remainder of the command is supplied by the Huffman State Machine.

- 5       Figure 121 depicts flow charts for the Huffman decoding of both AC and DC Coefficients.

Dealing first with the process for AC Coefficients, the process starts by reading a VLC using the appropriate tables (there are two AC tables). The Huffman index is then converted into the RUN and SIZE values in the Index to Data Unit. Two values are trapped at the Huffman Index stage, these are for EOB and ZRL. These are the only two values for which no FLC bits are read. In the case when the decode index is neither of these two values, the Huffman Decoder immediately reads one bit of FLC while it waits for the Index to Data Unit to complete the look-up operation to determine how many bits are actually required. In the case of EOB, no further processing is performed by the Huffman State Machine in the Huffman Decoder and another command is read from the Parser State Machine.

In the case of ZRL, no FLC bits are required but the block is not completed. In this case, the Huffman decoder immediately commences decoding a further VLC (using the same table as before).

- 25       There is a particular problem with detecting the index values associated with ZRL and EOB. This is because (unlike H.261 and MPEG) the Huffman tables are downloadable. For each of the two JPEG AC tables, two registers are provided (one for ZRL and one for EOB). These are loaded when the table is downloaded. They hold the value of index associated with the appropriate symbol.

The ALU must convert the SIZE bit FLC code to the appropriate sign-magnitude value. These are loaded when the table is downloaded. They hold the value of index associated with the appropriate symbol.

The ALU must convert the SIZE bit FLC code to the appropriate sign-magnitude value. This can be done by

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first sign-extending the value with the *wrong* sign. If the sign bit is now set, then the remaining bits are inverted (ones complement).

In the case of DC Coefficients, the decision making in the Huffman Decoding Stage is somewhat easier because there is no equivalent of the ZRL field. The only symbol which causes zero FLC bits to be read is the one indicating zero DC difference. This is again trapped at the Huffman Index stage, a register being provided to hold this index for each of the (downloadable) JPEG DC tables.

The ALU of the present invention has the job of forming the final decoded DC coefficient by retaining a copy of the last DC Coefficient value (known as the prediction). Four predictors are required, one for each of the four active color components. When the DC difference has been decoded, the ALU adds on the appropriate predictor to form the decoded value. This is stored again as the predictor for the next DC difference of that color component. Since DC coefficients are signed (because of the DC offset) conversion from twos complement to sign magnitude is required. The value is then output with a RUN of zero. In fact, the instructions to perform some of the last stages of this are not supplied by the Huffman State Machine. They are simply executed by the Parser State Machine.

In a similar manner to the AC Coefficients, the ALU must first form the DC difference from the SIZE bits of FLC. However, in this case, a twos complement value is required to be added to the predictor. This can be formed by first sign extending with the wrong sign, as before. If the result is negative, then one must be added to form the correct value. This can, of course, be added at the same time as the predictor by jamming the carry into the adder.

#### B.2.2.3 Error Handling

Error handling deserves some mention. There are effectively four sources of error that are detected:

- Ran off the end of a table.
- Serial when token expected.

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- Token when serial expected.
- Too many coefficients in a block.

The first of these occurs in two situations. If the bit counter reaches sixteen (legal values being 0 to 15) then  
 5 an error has occurred because the longest legal Huffman code is sixteen bits. If any intermediate value of "index" exceeds 255 then an error has occurred as described in section B.2.2.1.3.

The second occurs when serial data is encountered when a  
 10 Token was expected. The third when the opposite condition arises.

The last type of error occurs if there are too many coefficients in a block. This is actually detected in the Index to Data Unit.

15 When any of these conditions arises, the error is noted in the Huffman error register and the Parser state machine is interrupted. It is the responsibility of the Parser State Machine to deal with the error and to issue the commands necessary to recover.

20 The Huffman cooperates with the Parser State Machine at the time of the interrupt in order to assure correct operation. When the Huffman Decoder interrupts the Parser State Machine, it is possible that a new command is waiting to be accepted at the output of the Parser State Machine.  
 25 The Huffman Decoder will not accept this command for two whole cycles after it has interrupted the Parser State Machine. This allows the Parser State Machine to remove the command that was there (which should not now be executed) and replace it with an appropriate one. After  
 30 these two cycles, the Huffman Decoder will resume normal operation and accept a command if a valid command is there. If not, then it will do nothing until the Parser State Machine presents a valid command.

When any of these errors occur, the "Huffman Error" event  
 35 bit is set and, if the mask bit is set, the block will stop and the controlling microprocessor will be interrupted in the normal manner.

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token will be encountered in place of the 4 bit FLC. This requirement is not foreseen and, therefore, an "Ignore Errors" command bit has been added.

#### B.2.2.4 Huffman Commands

5 Here are the bits used by the Parser State Machine to control the Huffman Decoder block and their definitions. Note that the Index to Data Unit command bits are also included in this table. From the microprogrammer's point of view, the Huffman Decoder and the Index to Data Unit  
10 operate as one coherent logical block.

| Bit | Name          | Function                                                                                      |
|-----|---------------|-----------------------------------------------------------------------------------------------|
| 11  | Ignore Errors | Used to disable errors in certain circumstances.                                              |
| 10  | Download      | Either nominate a table for download or download data into that table.                        |
| 9   | Alutab        | Use information from the ALU registers to specify the table number (or number of bits of FLC) |
| 8   | Bypass        | Bypass the Index to Data Unit                                                                 |
| 7   | Token         | Decode a Token rather than FLC or VLC                                                         |
| 6   | First Coeff   | Selects first coefficient index for Tcoeff table and other special modes.                     |
| 5   | Special       | If set the Huffman State machine should take over control.                                    |
| 4   | VLC (not FLC) | Specify VLC or FLC                                                                            |
| 3   | Table[3]      | Specify the table to use for VLC                                                              |

Table B.2.2 Huffman Decoder Commands

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|   |          |                                         |
|---|----------|-----------------------------------------|
| 2 | Table[2] | or the number of bits to read for a FLC |
| 1 | Table[1] |                                         |
| 0 | Table[0] |                                         |

**Table B.2.2 Huffman Decoder Commands**

**B.2.2.4.1 Reading FLC**

In this mode, Ignore Errors, Download, Alutab, Token, First Coeff, Special and VLC are all zero. Bypass will be set so that no Index to Data translation occurs.

The binary number in Table[3:0] indicates how many bits are to be read.

The numbers 0 to 12 are legal. The value zero does indeed read zero bits (as would be expected) and this instruction is, therefore, the Huffman Decoder NOP instruction. The values 13, 14 and 15 will not work and the value 15 is used when the Huffman State Machine is in control to denote the use of "SSSS" as the number of bits of FLC to read.

**15    B.2.2.4.2 Reading VLC**

In this mode, Ignore Errors, Download, Alutab, Token, First Coefficient and Special are zero and VLC is one. Bypass will usually be zero so that Index to Data translation occurs.

20    In this mode Token, First Coefficient and Special are all zero, VLC is one.

The binary number in Table[3:0] indicates which table to use as shown:

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| Table[3:0] | VLC Table to use              |
|------------|-------------------------------|
| 0000       | TCoefficient (MPEG and H.261) |
| 0001       | CBP (Coded Block Pattern)     |
| 0010       | MBA (Macroblock Address)      |
| 0011       | MVD (Motion Vector Data)      |
| 0100       | Intra Mtype                   |
| 0101       | Predicted Mtype               |
| 0110       | Interpolated Mtype            |
| 0111       | H.261 Mtype                   |
| 10x0       | JPEG (MPEG) DC Table 0        |
| 10x1       | JPEG (MPEG) DC Table 1        |
| 11x0       | JPEG AC Table 0               |
| 11x1       | JPEG AC Table 1               |

**Table B.2.3 Huffman Tables**

Note that in the case of the tables held in RAM (i.e., the JPEG tables) bit 1 is not used so that the table selections occur twice. If a non-baseline JPEG decoder is built, then there will be four DC tables and four AC tables and Table[1] will then be required.

If Table[3] is zero, then the input data is inverted as it is used in order that the tables are read correctly as H.261 style tables. In the case of Table[3:0]=0, the appropriate Ring modification is also applied.

**B.2.2.4.3 NOP Instruction**

As previously described, the action of reading a FLC of zero bits is used as a No Operation instruction. No data is read from the input ports (either Token or Serial) and  
 5 the Huffman Decoder outputs a data value of zero along with the instruction word.

**B.2.2.4.4 TCoefficient First Coefficient**

The H.261 and MPEG TCoefficient Table has a special non-Huffman code that is used for the very first coefficient in  
 10 the block. In order to decode a TCoefficient at the start of a block, the First Coefficient bit may be set along with a VLC instruction with table zero. One of the many effects of the First Coefficient bit is to enable this code to be decoded.

15 Note that in normal operation, it is unusual to issue a "simple" command to read a TCoefficient VLC. This is because control is usually handed to the Huffman Decoder by setting the Special Bit.

**B.2.2.4.5 Reading Token Words**

20 In order to read Token words, the Token bit should be set to one. The Special and First Coefficient bits should be zero. The VLC bit should also be set if the Table[0] bit is to work correctly.

In this mode, the bits Table[1] and Table[0] are used to  
 25 modify the behavior of the Token reading as follows:

| Bit      | Meaning                             |
|----------|-------------------------------------|
| Table[0] | Discard padding bits of serial data |
| Table[1] | Discard all serial data.            |

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

If both Table[0] and Table[1] are zero, then the presence of serial data before the token is considered to be an error and will be signalled as such.

If Table [1] is set, then all serial data is discarded until a Token Word is encountered. No error will be caused by the presence of this serial data.

If Table[0] is set, then padding bits will be discarded. It is, of course, necessary to know the polarity of the padding bits. This is determined by Table[3] in exactly the same way as for reading VLC data. If Table [3] is zero, input data is first inverted and then any "one" bits are discarded. If Table [3] is set to one, the input data is NOT inverted and "one" bits are discarded. Since the action of inverting the data depending upon the Table[3] bit is conditional on the VLC bit, this bit must be set to one. If any bits that are not padding bits are encountered (i.e., "1" bits in H.261 and MPEG) an error is reported.

Note that in these instructions only a single Token word is read. The state of the extension bit is ignored and it is the responsibility of the Demux to test this bit and act accordingly. Instructions to read multiple words are also provided - see the section on Special Instructions.

#### B.2.2.4.6 ALU Registers Specify Table

If the "Alutab" bit is set, registers in the ALU's register file can be used to determine the actual table number to use. The table number supplied in the command, together with the VLC bit, determines which ALU registers are used;

**Table B.2.4 ALU Register Selection**

| VLC | table(3:0) | ALU table       |
|-----|------------|-----------------|
| 0   | x0xx       | lwd_r_size      |
| 0   | x1xx       | bwd_r_size      |
| 1   | x0xx       | dc_huff(compid) |
| 1   | x1xx       | ac_huff(compid) |

In the case of fixed length codes, the correct number of bits are read for decoding the vectors. If r\_size is zero, a NOP instruction results.

In the case of Huffman codes, the generated table number  
5 has table[3] set to one so that the resulting number refers to one of the JPEG tables.

#### B.2.2.4.7 Special Instructions

All of the instructions (or modes of operation) described thus far are considered as "Simple" instructions. For each  
10 command that is received, the appropriate amount of input data (of either serial or token data) is read and the resulting data is output. If no error is detected, exactly one output will be generated per command.

In the present invention, special instructions have the  
15 characteristic that more than one output word may be generated for a single command. In order to accomplish this function, the Huffman Decoder's internal State Machine takes control and will issue itself instructions as required until it decides that the instruction which the  
20 Parser requested has been complete.

In all Special instructions, the first real instruction of the sequence that is to be executed is issued with the Special bit set to one. This means that all sequences must have a unique first instruction. The advantage of this  
25 scheme is that the first real instruction of the sequence is available without a look-up operation being required based upon the command received from the Parser.

There are four recognized special instructions:

- TCoefficient
- 30 ·JPEG DC
- JPEG AC
- Token

The first of these reads H.261 and MPEG Transform coefficients, and the like, until the end-of-block symbol  
35 is read. If the block is a non-intra block, this command will read the entire block. In this case, the "First Coefficient" bit should be set so that the first

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Therefore, an instruction attempting to read a VLC that is issued immediately after a table download instruction will fail. There is no reason why such a sequence should occur in any real application (i.e., when doing JPEG). It is, however, possible to build simulation tests that do this.

#### B.2.2.5 Huffman State Machine

The Huffman State Machine, in accordance with the present invention, operates to provide the Huffman Decoder commands that are internally generated in certain cases. All of the commands that may be generated by the internal state machine may also be provided to the Huffman Decoder by the Demux.

The basic structure of the State Machine is as follows. When a command is issued to the Huffman Decoder, it is stored in a series of auxiliary latches so that it may be reused at a later time. The command is also executed by the Huffman Decoder and analyzed by the Huffman State Machine. If the command is recognized as being the first of a known instruction sequence and the SPECIAL bit is set, then the Huffman Decoder State Machine takes over control of the Huffman Decoder from the Parser State Machine.

At this point, there are three sources of instructions for the Huffman Decoder:

- 1) The Parser State Machine - this choice is made at the completion of the special instruction (e.g., when EOB has been decoded) and the next demux command is accepted.
- 2) The Huffman State Machine. The Huffman State Machine may provide itself with an arbitrary command.
- 3) The original instruction that was issued by the Parser State Machine to start the instruction.

In case (2), it is possible that the table number is provided by feedback from the Index to Data Unit, this would then replace the field in the Huffman State Machine ROM.

In case (1), in certain instances, table numbers are

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to be the next instruction from the Parser. The exact function of the comparator is controlled by bits in the Huffman State Machine ROM.

Behind the EOB comparator, there are four registers holding the index of the EOB symbol in the AC and DC JPEG tables. In the case of the DC tables, there is of course no End-Of-Block symbol but there is the zero-size symbol, that is generated by a DC difference of zero. Since this causes zero bits of FLC to be read in exactly the same way as the EOB symbol, they are treated identically.

In addition to the four index values held in registers, the constant value, 1, can also be used. This is the index number of the EOB symbol in H.261 and MPEG.

#### B.2.2.5.2 ZRL Comparator

In the present invention, this is the more general purpose comparator. It causes the choice of either the Huffman State Machine instruction or the Original Instruction for use by the I to D.

Behind the ZRL comparator, there are four values. Two are in registers and hold the index of the ZRL code in the AC tables. The other two values are constants, one is the value zero and the other is 12 (the index of ESCAPE in MPEG and H.261).

The constant zero is used in the case of an FLC. The constant 12 is used whenever the table number is less than 8 (and VLC). One of the two registers is used if the table number is greater than 7 (and VLC) as determined by the low order bit of the table number.

A bit in the state machine ROM is provided to enable the comparator and another is provided to invert its action.

If the TOKEN bit in the instruction is set, the comparator output is ignored and replaced instead by the extn bit. This allows for running until the end of a Token.

#### B.2.2.5.3 Huffman State Machine ROM

The instruction fields in the Huffman State Machine are as follows:

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002707" 00269960

nxtstate[4:0]

The address to use in the next cycle. This address may be modified.

statectl

- 5 Allows modification of the next state address. If zero, the state machine address is unmodified, otherwise the LSB of the address is replaced by the value of either of the two comparators as follows:

| nxtstate[0] |                          |
|-------------|--------------------------|
| 0           | Replace Lsb by EOB match |
| 1           | Replace Lsb by ZRL match |

- Note: in any case, if the next Huffman Instruction is selected as "Re-run original command" the state machine will jump to location 0, 1, 2 or 3 as appropriate for the command.

eobctl[1:0]

- This controls the selection of the next Huffman instruction based upon the EOB comparator and extn bit as follows:

| eobctl[1:0] |                                       |
|-------------|---------------------------------------|
| 00          | No effect - see zrlctl[1:0]           |
| 01          | Take new (Parser) command if EOB      |
| 10          | Take new (Parser) command if extn low |
| 11          | Unconditional Demux Instruction       |

zrlctl[1:0]

This controls the selection of the next Huffman instruction based upon the ZRL comparator. If the

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instruction. However, if the ZRL comparator matches then the `zrltab[3:0]` field is used in preference.

If it is not required that a different table number be used depending upon whether a ZRL match occurs, then both  
 5 `smtab[3:0]` and `zrltab[3:0]` will have the same value. Note, however, that this can lead to strange simulation problems in Lsim. In the case of MPEG, there is no obvious requirement to load the register that indicate the Huffman index number for ZRL (a JPEG only construction). However,  
 10 these are still selected and the output of the ZRL comparator becomes "unknown" despite the fact that both `smtab[3:0]` and `zrltab[3:0]` have the same value in all cases that the ZRL comparator may be "unknown" (so it does not matter which is selected) the next state still goes to  
 15 "unknown".

`zrltab[3:0]`

This is the table number that will be used by the Huffman Decoder if the selected instruction is the state machine instruction and the ZRL comparator matches.

20 `smvlc`

This is the VLC bits used by the Huffman Decoder if the selected instruction is the state machine instruction.

`aluzrl[1:0]`

This field controls the selection of the instruction that  
 25 is passed to the ALU. It will either be the command from the Parser State Machine (that was stored at the start of the instruction sequence) or the command from the state machine:

| <code>aluzrl[1:0]</code> |                                                    |
|--------------------------|----------------------------------------------------|
| 00                       | Always take the saved Parser State Machine Command |
| 01                       | Always take the Huffman State Machine Command      |
| 10                       | Take the Huffman SM command if not EOB             |
| 11                       | Take the Huffman SM command if not ZRL             |

`alueob`

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This wire controls modification of the instruction passed to the ALU based upon the EOB comparator. This simply forces the ALU's output mode to "zinput". This is an arbitrary choice; any output mode apart from "none" will suffice. This is to ensure that the end-of-lock command word is passed to the Token Formatter block where it controls the proper formatting of DATA Tokens:

| alueob |                                         |
|--------|-----------------------------------------|
| 0      | Do not modify ALU outsrc field          |
| 1      | Force "zinput" into outsrc if EOB match |

The remainder of the fields are the ALU instruction fields. These are properly documented in the ALU description.

#### B.2.2.5.4 Huffman State Machine Modification

In one embodiment of the state machine, the Index to Data Unit needs to "know" when the RUN part of an escape-coded Tcoefficient is being passed to the Index to Data Unit. While this can be accomplished using an appropriate bit in the control ROM, but to avoid changing the ROM, an alternative approach has been used. In this regard, the address going into the ROM is monitored and the address value five is detected. This is the appropriate location designated in the ROM dealing with the RUN field. Of course, it will be apparent that the ROM could be programmed to use other selected address values. Moreover, the aforescribed approach of using a bit in the control ROM could be utilized.

#### B.2.2.6 Guided Tour of Schematics

In the present invention, the Huffman Decoder is called "hd". Logically, "hd" actually includes the Index to Data Unit (this is required by the limitations of compiled code generation). Accordingly, "hd" includes the following





signal is another (since no data should be read from the input shifter even though an output is produced to signal EOB) and lastly table download nomination is a third.

notfrczero (generated by a FLC of size zero, a NOP)  
 5 ensures that the result is zero when a NOP instruction is used. Furthermore, invert indicates when the serial bits should be inverted before Huffman decoding (see section B.2.2.1.1). ring indicates when the transform coefficient ring should be applied (see section B.2.2.1.2).

10 Decoding is also accomplished regarding addressing the codes-per-bit ROMs. These are built out of the small datapath ROMs. The signals are duplicated (e.g., csha and csla) purely to get sufficient drive by separating the ROMs into two sections. The address can be taken either from  
 15 the bit counter (bit[3:0]) or from the microprocessor interface address (key-addr[3:0]) depending upon UPI access to the block being selected.

Additional decoding is concerned with the UPI reading of registers such as those that hold the Huffman index values  
 20 for the JPEG tables (EOB, ZRL etc.). Also included is a tristate driver control for these registers and the UPI reading of the codes per bit RAMs.

Arithmetic datapath decoding is also provided for certain important bit numbers. first\_bit is used in connection  
 25 with the Tcoeff first coefficient trick and bit\_five is concerned with applying the ring in the Tcoeff table. Note the use of forceeob to simulate the action that the EOB comparator matches the decoded index value.

Regarding the extn bit, if a token is read from the input  
 30 shifter, then the associated extn bit is read along with it. Otherwise, the last value of extn is preserved. This allows the testing of the extn bit by the microcode program at any time after a token has been read.

When zerodat is asserted, the upper four bits of the  
 35 Huffman output data are forced to zero. Since these only have valid values when decoding fixed length codes, they are zeroed when decoding a VLC, a token or when a NOP



instruction is executed for any reason.

Further circuitry detects when each command is completed and generates the "done" signals. Essentially, there are two groups of reasons for being "done"; normal reasons and  
 5 exceptional reasons. These are each handled by one of the two three way multiplexers.

The lower multiplexer (i\_1275) handles the normal reasons. In the case of a FLC, the signal ndnflc is used. This is the output of the comparator comparing the bit  
 10 counter with the table number. In the case of a VLC, the signal ndnvlc is used. This is an output from the arithmetic datapath and reflects directly Equation 9. In the case of an NOP instruction or a Token, only one cycle is required and, therefore, the system is unconditionally  
 15 "done".

In the present invention, the upper multiplexer (i\_1274) handles exceptional cases. If the decoder is expecting a size to be fed back (fbexpctd0) in JPEG decoding and that size is one (notfbone0), then the decoder is done because  
 20 only one bit is required. If the decoder is doing the first bit of the first coefficient using the Tcoeff table, it is done if bit zero of the current index is zero (see Section B.2.2.1.2). If neither of these conditions are met then there is no exceptional reason for being done.

The NOR gate (i\_1293) finally resolves the "done" condition. The condition generated by i-570 (i.e., that the data is not valid) forces "done". This may seem a little strange. It is used primarily just after reset to  
 25 force the machine into its "done" state in preparation for the first command ("done" resets all counters, registers, etc.). Note that any error condition also forces "done".

The signal notdonex is required for use in detecting errors. The normal "done" signals cannot be used since on detecting an error "done" is forced anyway. The use of  
 35 "done" would give a combinatorial feedback loop.

Error detection and handling, is accomplished by circuitry which detects all of the possible error

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conditions. These are ORed together in i\_1190. In this case, i\_1193, i\_585 and i\_584 constitute the three bit Huffman error register. Note i\_1253 and i\_1254 which disable the error in the cases when there is no "real" error (section B.2.2.3).

In addition, i\_580 and i\_579 along with the associated circuitry provide a simple state machine that controls the acceptance of the first command after an error is detected.

As previously indicated, control signals are delayed to match pipeline delays in the Index to Data Unit and the ALU.

Itod\_bypass is the actual bypass signal passed to the Index to Data Unit. It is modified when the Huffman State Machine is in control to force bypass whenever a fixed length code is decoded.

Aluinstr[32] is the bit that causes the ALU to feedback (condition codes) to the Parser State Machine. Furthermore, it is important when the Huffman State Machine is in control that the signals are only asserted once (rather than each time one of the primitive commands completes).

Aluinstr[36] is the bit that allows the ALU to step the block counters (if other ALU instruction bits specify an increment too). This also must only be asserted once.

In addition, these bits must only be asserted for ALU instructions that output data to the Token Formatter. Otherwise, the counters may be incremented prior to the first output to the Token formatter causing an incorrect value of "cc" in a DATA token.

In the illustrated embodiment of the invention, either alunode[1] or alunode[0] will be low if the ALU will output to the Token Formatter.

Figure 118, similar to Figure 27, illustrates the Huffman State Machine datapath referred to as "hdstdp". There is also a UPI decode for reading the output of the Huffman State machine ROM.

Multiplexing is provided to deal with the case when the

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table number is specified by the ALU register file locations (see Section B.2.2.4.6).

The modification of `aluinstr[3:2]` deals with forcing the ALU `outsrc` instruction field to non-none (section 5 B.2.2.5.3, description of `alueob`)

Regarding the command register for the Huffman Decoder block (x), each bit of the command has associated multiplexer which selects between the possible sources of commands. Four control signals control this selection:

10     `Selhold` causes the register to retain its current state.

`Selnew` causes a new command to be loaded from the Parser State Machine. This also enables loading of the registers that retain the original Parser State Machine command for later use.

15     `Selold` causes loading of the command from the registers that retain the original Parser State Machine command.

`/selism` causes loading of the command from the Huffman State Machine ROM.

In the case of the table number, the situation is slightly more complicated since the table number may also 20 be loaded from the output data of the Index to Data Unit (`selholdt` and `muxsize`). Latches hold the current address in the Huffman state machine ROM. The logic detects which of the possible four commands are being executed. These 25 signals are combined to form the lower two bits of the start address in the case of a new command.

Logic also detects when the output of the state machine ROM is meaningless (usually because the command is a "simple" command). The signal `notignorerom` effectively 30 disables operation of the state machine, in particular, disabling any modification of the instruction passed to the ALU.

The circuitry generating `fixstate0` controls the limited jumping capability of this state machine.

35     Decoding is also provided for driving the signals into the Huffman State Machine ROM. This is datapath-style combinatorial ROM.

Decoding also provides for the registers that hold the Huffman Index number for symbols such as ZRL and EOB. These registers can be loaded from the UPI or the datapath. The decoding in the center(es[4:0] and zs[3:0]) is generating the select signals for the multiplexers that select which register or constant value to compare against the decode Huffman Index.

15 In the present invention, the signals notnew, notsm and  
notold are used on sheet 10 to control the operation of the  
Huffman Decoder command register. They are generated here  
in an obvious manner from the control bits in the state  
machine ROM (described in Section B.2.2.5.3) together with  
20 the output of the Huffman Index comparators (neobmatch and  
nzrlmatch).

In the case when the end-of-block has not been encountered, one of aluselmx (selecting the Parser State Machine instruction) or aluselms (selecting the Huffman state machine instruction) will be generated.

A register holds the nominated table number during table download. Decoding is provided for the codes-per-bit RAMs.

Additional decoding recognizes when symbols like EOB and ZRL are downloaded so that the Huffman Index number registers can be automatically loaded.

Regarding the bit counter, a comparator detects when the correct number of bits have been read when reading a FLC.

#### B.2.2.6.2 Description of "hddp"

Comparators detect the specific values of Huffman Index. Registers hold the values for the downloadable tables. The multiplexers (meob[7:0] and mzc[7:0]) select which value to use and the exclusive-or gates and gating constitute the comparators.

Adders and registers directly evaluate the equations described in Section B.2.2.1. No further description is thought necessary here. An exclusive or is used for inverting the data (i\_807) described in Section B.2.2.1.1.

The "code" register is 12 bits wide. A multiplexing arrangement implements the "ring" substitution described in Section B.2.2.1.2.

Regarding the pipeline delays for data and multiplexing between decoded serial data (index[7:0]) and Token data (ntoken0[7:0]), the Huffman index value is decided in ZRL and EOB symbols.

Codes-per-bit ROMs and their multiplexing are used for deciding which table to use. This arrangement is used because the table select information arrives late. All tables are then accessed and the correct table selected.

Regarding the codes-per-bit RAM, the final multiplexing of the codes-per-bit ROM and the output of the codes-per-bit RAM takes place inside the block "hdcpram".

#### B.2.2.6.3 Description of "hdstdp"

In the present invention, "Hdstdp" comprises two modules. "hdstdel" is concerned with delaying the Parser State Machine control bits until the appropriate pipeline stage, e.g., when they are supplied to the ALU and Token Formatter. It only processes about half of the instruction word that is passed to the ALU, the remainder being dealt with by the other module "hdstmod".

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"Hdstmod" includes the Huffman State Machine ROM. Some bits of this instruction are used by the Huffman State Machine control logic. The remaining bits are used to replace that part of the ALU instruction word (from the Parser State Machine) that is not dealt with in "hdstdel".

"Hdstmod" is obvious and requires no explanation - there are only pipeline delay registers.

"Hdstdel" is also very simple and is handled by a ROM and multiplexers for modifying the ALU instruction. The remainder of the circuitry is concerned with UPI read access to half of the Huffman State Machine ROM outputs. Buffers are also used for the control signals.

### B.2.3 The Token Formatter

The Huffman Decoder Token Formatter, in accordance with the present invention, sits at the end of the Huffman block. Its function, as its name suggests, is to format the data from the Huffman Decoder into the propriety Token structure. The input data is multiplexed with data in the Microinstruction word, under control of the Microinstruction word command field. The block has two operating modes; DATA\_WORD, and DATA\_TOKEN.

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

### B.2.3.1 The Microinstruction Word

Table B.2.7 The Microinstruction word consisting of seven fields

| Field Name         | Bits  |
|--------------------|-------|
| Token              | 0:7   |
| Mask               | 8:11  |
| Block Type (Bt)    | 12:13 |
| External Extn (Ee) | 14    |
| Demux Extn (De)    | 15    |
| End of Block (Eb)  | 16    |
| Command (Cmd)      | 17    |

|     |    |    |    |    |      |       |
|-----|----|----|----|----|------|-------|
| 17  | 16 | 15 | 14 | 12 | 8    | 0     |
| Cmd | Eb | De | Ee | Bt | Mask | Token |

The Microinstruction word is governed by the same accept as the Data word.

The Microinstruction word is governed by the same accept as the Data word.

### B.2.3.2 Operating Modes

Table B.2.8 Bit Allocation

| Cmd | Mode       |
|-----|------------|
| 0   | Data_Word  |
| 1   | Data_Token |

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B.2.3.2.1 Data Word

In this mode, the top eight bits of the input are fed to the output. The bottom eight bits will be either the bottom eight bits of the input, the Token field of the  
 5 Microinstruction word or a mixture of both, depending on the mask field. Mask represents the number of input bits in the mix, i.e.

```
out_data[16:8]=in_data[16:8]
```

```
out_data[7:0]=(Token[7:0]&(ff<<mask))indata[7:0]
```

10 When mask is set to 0 x 8 or greater, the output data will equal the input data. This mode is used to output words in non-DATA Tokens. With mask set to 0, out\_data[7:0] will be the Token field of the Microinstruction word. This mode is used for outputting Token headers that contain no  
 15 data. When Token headers do contain data, the number of data bits is given by the mask field.

If External Extn(Ee) is set, out\_extn=in\_extn,  
 otherwise

out\_extn=De.Bt and Eb are "don't care".

20 B.2.3.2.2 Data Token

This mode is used for formatting DATA Tokens and has two functions dependent on a signal, first\_coefficient. At reset, first\_coefficient is set. When the first data coefficient arrives along with a Microinstruction word that  
 25 has cmd set to 1, out\_data[16:2] is set to 0 x 1 and out\_data[1:0] takes the value of the Bt field in the Microinstruction word. This is the header of a DATA Token. When this word has been accepted, the coefficient that accompanied the command is loaded into a register, RL and  
 30 first\_coefficient takes the value of Eb. When the next coefficient arrives, out\_data[16:0] takes the previous coefficient, stored in RL. RL and first\_coefficient are then updated. This ensures that when the end of the block is encountered and Eb is set, first\_coefficient is set,  
 35 ready for the next DATA Token, i.e.,

00000000-101000



```

if(first_coefficient)
{
    out_data[16:2] = 0x1
    out_data[1:0] = Bt[1:0]
    RL[16:0] = in_data[16:0]
}
else
{
    out_data[16:0] = RL[16:0]
    RL[16:0] = in_data[16:0]
}
out_extn = -Eb

```

### B.2.3.3 Explanatory Discussion

In accordance with the present invention, most of the instruction bits are supplied in the normal manner by the Parser State Machine. However, two of the fields are actually supplied by other circuitry. The "Bt" field mentioned above is connected directly to an output of the ALU block. This two bit field gives the current value of "cc" or "color component". Thus, when a DATA Token header is constructed, the lowest order two bits take the color component directly from the ALU counters. Secondly, the "Eb" bit is asserted in the Huffman decoder whenever and End-of-block symbols id decoded (or in the case of JPEG when one is assumed because the last coefficient in the block is coded).

The in\_extn signal is derived in the Huffman Decoder. It only has meaning with respect to Tokens when the extension bit is supplied along with the Token word in the normal way.

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#### B.2.4 The Parser State Machine

The Parser State Machine of the present invention is actually a very simple piece of circuitry. The complication lies in the programming of the microcode ROM which is discussed in Section B.2.5.

Essentially the machine consists of a register which holds the current address. This address is looked up in the microcode ROM to produce the microcode word. The address is also incremented in a simple incrementer and this incremented address is one of two possible addresses to be used for the next state. The other address is a field in the microcode ROM itself. Thus, each instruction is potentially a jump instruction and may jump to a location specified in the program. If the jump is not taken, control passes to the next location in the ROM.

A series sixteen condition code bits are provided. Any one of these conditions may be selected (by a field in the microcode ROM) and, in addition, it may be inverted (again a bit in the microcode ROM). The resulting signal selects between either the incremented address or the jump address in the microcode ROM. One of the conditions is hard-wired to evaluate as "False". If this condition is selected, no jump will occur. Alternatively, if this condition is selected and then inverted, the jump is always taken; an unconditional jump.

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Table B.2.9 Condition Code Bits

| Bit No. | Name        | Description                                                                                                                                                                                                                                                                                                 |
|---------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0       | user[0]     | Connected to a register programmable by the user from the microprocessor interface. They allow "User defined" condition codes that can be tested with little overhead. Two are defined to control non-standard "Coded block Pattern" processing for experimental 4 block and 8 block macroblock structures. |
| 1       | user[1]     |                                                                                                                                                                                                                                                                                                             |
| 2       | ccp_eight   |                                                                                                                                                                                                                                                                                                             |
| 3       | ccp_special |                                                                                                                                                                                                                                                                                                             |
| 4       | he[0]       | These bits connect directly to the Huffman decoder's Huffman Error register.                                                                                                                                                                                                                                |
| 5       | he[1]       |                                                                                                                                                                                                                                                                                                             |
| 6       | he[2]       |                                                                                                                                                                                                                                                                                                             |
| 7       | Extn        | The Extension bit (for Tokens)                                                                                                                                                                                                                                                                              |
| 8       | Blkptn      | The Block Pattern Shifter                                                                                                                                                                                                                                                                                   |
| 9       | MBstart     | At Start of a Macroblock                                                                                                                                                                                                                                                                                    |
| 10      | Picstart    | At Start of a Picture                                                                                                                                                                                                                                                                                       |
| 11      | Restart     | At Start of a Restart interval                                                                                                                                                                                                                                                                              |
| 12      | Chngdet     | The "Sticky" Change Detect bit                                                                                                                                                                                                                                                                              |
| 13      | Zero        | ALU zero condition                                                                                                                                                                                                                                                                                          |
| 14      | Sign        | ALU sign condition                                                                                                                                                                                                                                                                                          |
| 15      | False       | Hard wired to False.                                                                                                                                                                                                                                                                                        |

#### B.2.4.1 Two wire Interface Control

The two-wire interface control, in accordance with the invention, is a little unusual in this block. There is a two-wire interface between the Parser State Machine and the Huffman Decoder. This is used to control the progress of commands. The Parser State Machine will wait until a given command has been accepted before it proceeds to read the next command from the ROM. In addition, condition codes are fed back through a wire from the ALU.

Each command has a bit in the microcode ROM that allows it to specify that it should wait for feedback. If this occurs, then after that instruction has been accepted by the Huffman Decoder, no new commands are presented until

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## 20

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5       A Huffman event is rather different. The condition being monitored is the "OR" of the three Huffman Error bits. In reality, this condition is handled in a very similar manner to the Parser Event. However, an additional wire from the Huffman Decoder, huffintrpt, is asserted whenever an error  
10 occurs. This causes control to jump to an error handler in the microcode program.

It is possible for huffintrpt to be asserted without a Huffman error being generated. This occurs in the special case of a "no-error" error as discussed in Section B.2.2.3. In this case, no interrupt (to the microprocessor interface) is generated, but control is still passed to the error handler (in the microcode). Since the Huffman error register will be clear in this case, the microcode error handler can determine that this is the situation and respond accordingly.

There are several special locations in the microcode ROM. The first four locations in the ROM are entry points to the main program. Control passes to one of these four locations on reset. The location jumped to depends upon the coding standard selected in the ALU register, coding\_std. Since this location is itself reset to zero by a true reset control passes to location zero. However, it is possible to reset the Parser State Machine alone by using the UPI register bit CED\_H\_TRACE\_RST in CED H TRACE.

The second four locations (0 x 004 to 0 x 007) are used  
5 when a Huffman interrupt takes place. Typically, a jump to  
the actual error handler is placed in each of these  
locations. Again, the choice of location is made as a  
result of the coding standard.

10       As a diagnostic aid, a trace mechanism is implemented.  
This allows the microcode to be single-stepped. The bits  
CED\_H\_TRACE\_EVENT and CED\_H\_TRACE\_MASK in the register  
CED\_H\_TRACE control this. As their names suggest, they  
operate in a very similar fashion to the normal event bits.  
15       However, because of several differences (in particular no  
UPI interrupt is ever generated) they are not grouped with  
the other event bits.

### B.2.5 The Microcode

The code is instructed as follows:

Ucode.y is the main file. First, this includes tokens.h

to define the tokens. Next, regfile.h defines the ALU register map. The fields.u defines the various fields in the microcode word, giving a list of defined symbols for each possible bit pattern in the field. Next, the labels that are used in the code are defined. After this step, instr.u is included to define a large number of "cpp" macros which define the basic instructions. Then, errors.h defines the numbers which define the Parser events. Next, unword.u defines the order in which the fields are placed to build the microcode word.

The remainder of ucode.u is the microcode program itself.

#### B.2.5.1 The Instructions

In this section the various instructions defined in ucode.u are described. Not all instructions are described here since in many cases they are small variations on a theme (particularly the ALU instructions).

##### B.2.5.1.1 Huffman and Index to Data Instructions

In the invention, the H\_NOP instruction is used by the Huffman Decoder. It is the No-operation instruction. The Huffman does nothing in the sense that no data is decoded. The data produced by this instruction is always zero. Accordingly, the associated instruction is passed onto the ALU.

The next instructions are the Token groups; H\_TOKSRCH, H\_TOKSKIP\_PAD, H\_TOKSKIP\_JPAD, H\_TOKPASS and H\_TOKREAD. These all read a token or tokens from the Input Shifter and pass them onto the rest of the machine. H\_TOKREAD reads a single token word. H\_TOKPASS can be used to read an entire token, up to and including, the word with a zero extn bit. The associated command is repeated for each word of the Token. H\_TOKSRCH discards all serial data preceding a Token and then reads one token word. H\_TOKSKIP\_PAD skips any padding bits (H.261 and MPEG) and then reads one Token word. H\_TOKSKIP\_JPAD does the same thing for JPEG padding.

H\_FLC(NB) reads a fixed length code of "NB" bits.

H\_VLC(TBL) reads a vic using the indicated table (passed as mnemonic, e.g., H\_VLC(tccoeff)).

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H\_FLC\_IE(NB) is like H\_FLC, but the "ignore errors" bit is set.

H\_TEST\_VLC(TBL) is like H\_VLC, but the bypass bit is set so that the Huffman Index is passed through the Index to Data Unit unmodified.

H\_FWD\_R and H\_BWD\_R read a FLC of the size indicated by the ALU registers r\_fwd\_r\_size and r\_bwd\_r\_size, respectively.

H\_DCJ reads JPEG style DC coefficients, the table number from the ALU.

H\_DCH reads a H.261 DC term.

H\_TCOEFF and H\_DCTCOEFF read transform coefficients. In H\_DCTCOEFF, the first coeff bit is set and is for non-intra blocks, whilst H\_TCOEFF is for intra blocks after the DC term has already been read.

H\_NOMINATE(TBL) nominates a table for subsequent download.

H\_DNL(NB) reads NB bits and downloads them into the nominated table.

#### 20 B.2.5.1.2 ALU Instructions

There really are too many ALU instructions to explain them all in detail. The basic way in which the Mnemonics are constructed is discussed and this should make the instructions readable. Furthermore, these should readily be understandable to one of ordinary skill in the art.

Most of the ALU instructions are concerned with moving data from place to place and, therefore, a generic "load" instruction is used. In the Mnemonic, A\_LDxy, it is understood that the contents of y are loaded into x., i.e., the destination is listed first and the source second:



Table B.2.10 Letters used to denote possible sources and destinations of data

| Letter | Meaning           |
|--------|-------------------|
| A      | A register        |
| R      | Run register      |
| I      | Data input        |
| O      | Data Output       |
| F      | ALU register File |
| C      | Constant          |
| Z      | Constant of zero  |

By way of example, LDAI loads the A register with the data from the data input port of the ALU. If the ALU register file is specified, the mnemonic will take an address so that LDAF(RA) loads A with the contents of location RA in the register file.

The ALU has the ability to modify data as it is moved from source to destination. In this case, the arithmetic is indicated as part of the source data. Accordingly, the Mnemonic LDA\_AADDF(RA) loads A with the existing contents of the A register plus the contents of the indicated location in the register file. Another example is LDA\_ISGXR, which takes the input data, sign extends from the bit indicated in the RUN register, and stores the result in the A register.

In many cases, more than one destination for the same result is specified. Again, by way of example, LDF\_LDA\_ASUBC(RA) which loads the result of A minus a constant into both the A register and the register file.

Other mnemonics exist for specific actions. For example, "CLRA" is used for clearing the A register, "RMBC" to reset

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the macroblock counter. These are fairly obvious and are described in comments in instr.u.

One anomaly is the use of a suffix "\_O" to indicate that the result of the operation is output to the Token formatter in addition to the normal action. Thus  
 5 LDFI\_O(RA) stores the input data and also passes it to the token formatter. Alternatively, this could have been LDF\_LDO\_I(RA) if desired.

#### **B.2.5.1.3 Token Formatter Instructions**

10 This is the T\_NOP "No-operation" instruction. This is really a misnomer as it is impossible to construct a no-operation instruction. However, this is used whenever the instruction is of no consequence because the ALU does not output to the Token Formatter.

15 T-TOK output a Token word.

T\_DAT output a DATA Token word (used only with the Huffman State Machine instructions).

T-GENT8 generates a token word based on the 8 bits of constant field.

20 T\_GENT8E like T\_GENT8, but the extension bit is one.

T\_OPD(NB) NB bits of data from the bottom NB bits of the output with the remainder of the bits coming from the constant field.

T\_OPDE(NB) like T\_OPD, but the extension bit is high.

25 T\_OPD8 short-hand for T\_OPD(8)

T\_OPD8E short-hand for T\_OPDE(8)

#### **B.2.5.1.4 Parser State Machine Instructions**

This instruction, D\_NOP No-operation, i.e., the address increments as normal and the Parser State Machine does  
 30 nothing special. The Remainder of the instruction is passed to the data pipeline. No waiting occurs.

D\_WAIT is like D\_NOP, but waits for feedback to occur.

The simple jump group. Mnemonics like D\_JMP(ADDR) and D\_JNX(ADDR) jump if the condition is met. The instruction  
 35 is not output to the Huffman Decoder.

The external jump group. Mnemonics like D\_XJMP(ADDR) and D\_XJNX(ADDR). These are like their simple counterparts

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above, but the instruction is output to the Huffman Decoder.

The jump and wait group. Mnemonics like D\_WJNZ(ADDR). These instructions are output to the Huffman Decoder and the Parser waits for feedback from the ALU before evaluating the condition.

The following Mnemonics are used for the conditions themselves.

Table B.2.11 Mnemonics used for the conditions

| Mnemonic |         | Meaning                                             |
|----------|---------|-----------------------------------------------------|
| JMP      | .       | Unconditional jump                                  |
| JXT      | JNX     | Jump if extn=1 (extn=0)                             |
| JHE0     | JNHE0   | Jump if Huffman error bit 0 set (clear)             |
| JHE1     | JNHE1   | Jump if Huffman error bit 1 set (clear)             |
| JHE2     | JNHE2   | Jump if Huffman error bit 2 set (clear)             |
| JPTN     | .       | Jump if pattern shifter LSB is set                  |
| JPICST   | JNPICST | Jump is at picture start (not at picture start)     |
| JRSTST   | JNRSTST | Jump if at start of restart interval (not at start) |
| .        | JNCPBS  | Jump if not special CPS coding                      |
| .        | JNCPBB  | Jump if not 8 block (i.e. 4 block) macroblock       |
| JMI      | JPL     | Jump if negative (jump if plus)                     |
| JZE      | JNZ     | Jump if zero (jump if non-zero)                     |
| JCHNG    | JNCHNG  | Jump if change detect bit set (clear)               |
| JMBST    | JNMBST  | Jump if at start of macroblock (not at start)       |

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D\_DFLT for construction of a default instruction. This uses an event and then jumps to a location with the label flt". This instruction should never be executed since they are used to fill a ROM so that a jump to an unused location is trapped.

5

D\_ERROR causes an event and then jumps to a label "srch\_dispatch" which is assumed to attempt recovery from the error.

## SECTION B.3 HUFFMAN DECODER ALU

### B.3.1 Introduction

The Huffman Decoder ALU sub-block, in accordance with the present invention, provides general arithmetic and logical functionality for the Huffman Decoder block. It has the ability to do add and subtract operations, various types of sign-extend operations, and formatting of the input data into run-sign-level triples. It also has a flexible structure whose precise operation and configuration are specified by a microinstruction word which arrives at the ALU synchronously with the input data, i.e., under the control of the two-wire interface.

In addition to the 36-bit instruction and 12-bit data input ports, the ALU has a 6-bit run port, and an 8-bit constant port (which actually resides on the token bus). All of these, with the exception of the microinstruction word, drive buses of their respective widths through the ALU datapath. There is a single bit within the microinstruction word which represents an extension bit and is output together with the 17-bit-run-sign-level (out\_data). There is a two-wire interface at each end of the ALU datapath, and a set of condition codes which are output together with their own valid signal, cc\_valid. There is a register file which is accessible to other Huffman Decoder sub-blocks via the ALU, and also to the microprocessor interface.

### B.3.2.2 Basic Structure

The basic structure of the Huffman ALU is as shown in Figure 126. It comprises the following components:

- Input block 400
- Output block 401
- Condition Codes block 402
- "A" register 403 with source multiplexing
- Run register (6 bits) 404 with source multiplexing
- Adder/Subtractor 405 with source multiplexing
- Sign Extend logic 406 with source multiplexing
- Register file 407

Each of these blocks (except the output block) drives its output onto a bus running through the datapath, and these buses are, in turn, used as inputs to the multiplexing for block sources. For example, the adder output has its own datapath bus which is one of the possible inputs to the A register. Likewise, the A register has its own bus which forms one of the possible inputs to the adder. Only a subset of all possibilities exist in this respect, as specified in Section 7 on the microinstruction word.

In a single cycle, it is possible to execute either an add-based instruction or a sign-extend-based instruction. Furthermore, it is allowable to execute both of these in a single cycle provided that their operation is strictly parallel. In other words, add then sign extend or sign extend then add sequences are not allowed. The register file may be either read from or written to in a single cycle, but not both.

The output data has three fields:

- run - 6 bits
- sign - 1 bit
- level - 10 bits

If data is to be passed straight through the ALU, the least significant 11 bits of the input data register are latched into the sign and level fields.

It is possible to program limited multi-cycle operations of the ALU. In this regard, the number of cycles required is given by the contents of the register file location whose address is specified in the microinstruction, and the same operation is performed repeatedly while an iteration counter decrements to one. This facility is typically used to effect left shifts, using the adder to add the A register to itself and to store the result back in the A register.

### B.3.3 The Adder/Subtractor Sub-Block

This is a 12-bit wide adder, with optional invert on its input2 and optional setting of the carry-in bit. Output is a 12 bit sum, and carry-out is not used. There are 7 modes

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of operation:

### 15 B.3.4 The Sign Extend Sub-Block

In SGXMODE=NORMAL, all bits above (and including) the size-th bit, take the value of the size-th bit. All those below remain unchanged. Sign takes the value of the size-th bit. For example:

In SGXMOD=INVERSE, all bits above (and including) the size-th bit, take the inverse of the size-th bit, while all those below remain unchanged. Sign takes the inverse of the size-th bit. For example:

35        In SGXMODE=DIFMAG, if the size-th bit is zero, all the bits below (and including) the size-th bit are inverted, while all those above remain unchanged. If the size-th bit

is one, all bits remain unchanged. In both cases, sign takes the inverse of the size-th bit. This is used for obtaining the magnitude of AC difference values. For example:

```
5      data = 0000 1010 1010
      size = 2
      output = 0000 1010 1101, sign = 1
```

```
      data = 0000 1010 1010
      size = 1
10     output = 0000 1010 1010, sign = 0
```

In SGXMODE=DIFCOMP, all bits above (but not including) the size-th bit, take the inverse of the size-th bit, while all those below (and including) remain unchanged. Sign takes the inverse of the size-th bit. This is used for obtaining two's compliment values for DC difference values. For example:

```
15     data = 1010 1010 1010
      size = 0
      output = 1111 1111 1110, sign = 1
```

### 20 B.3.5 Condition Codes

There are two bytes (16 bits) of condition codes used by the Huffman block, certain bits of which are generated by the ALU/register file. These are the Sign condition code, the Zero condition code, the Extension condition code and a Change Detect bit. The last two of these codes are not really condition codes since they are not used by the Parser in the same way as the others.

```
25
30 The Sign, Zero and Extension condition codes are updated
    when the Parser issues an instruction to do so, and for
    each of these instructions the condition code valid signal
    is pulsed high once.
```

```
35 The Sign condition code is simply the sign extend sign
    output latched, while the Zero condition code is set to 1
    if the input to the A register is zero. The Extension
    condition code is the input extension bit latched
    regardless of OUTSRC.
```

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Condition codes may be used to evaluate certain condition types:

- result equals constant - use subtract and Zero condition
- 5 · result equals register value - use subtract and Zero condition
- register equals constant - use subtract and Zero condition
- register bit set - use sign extend and Sign condition
- 10 · result bit set - use sign extend and Sign condition

Note that when using the sign extend and Sign condition code combination, it is possible only to evaluate a single specified bit, rather than multiple bits as would be the case with a conventional logical AND.

- 15 The Change Detect bit, in the present invention, is generated using the same logic as for the Zero condition code, but it does not have an associated valid signal. A bit in the microinstruction indicates that the Change Detect bit should be updated if the value currently being
- 20 written to the register file is different from that already present (meaning that two clock cycles are necessary, first with REG-MODE set to READ and second with REGMODE set to WRITE). A microprocessor interrupt can then be initiated if a changed value is detected. The Change Detect bit is
- 25 reset by activating Change Detect in the normal way, but with REGMODE set to READ.

- The hardwired macroblock counter structure (which forms part of the register file- see below) also generates condition codes as follows: Mb\_Start, Pattern\_Code, Restart
- 30 and Pic\_Start.

#### B.3.6 The Register File

- The address map for the register file is shown below. It uses a 7-bit address space, which is common to both the ALU datapath and the UPI. A number of locations are not
- 35 accessed by the ALU, these typically being counters in the hardwired macroblock structure, and registers within the ALU itself. The latter have dedicated access, but form

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part of the address map for the UPI. Some multi-byte locations (denoted in the table by "O" for oversize) have a single ALU address, but multiple UPI addresses. Similarly, groups of registers which are indexed by the component count, CC (Indicated by "I" in the table) are treated as a single location by the ALU. This eases microprogramming for initialization and resetting, and also for block-level operations.

All of the locations, except the dedicated ALU registers (UPI read only), are read/write, and all of the counters are reset to zero by a bit in the instruction word. The pattern code register has a right shift capability, its least significant bit forming the Pattern\_Code condition bit. All registers in the hardwired macroblock structure are denoted in the table by "M", and those which are also counters (n-bit) are annotated with Cn.

In the present invention, certain locations have their contents hardwired to other parts of the Huffman subsystem-coding standard, two r-size locations, and a single location (2-bit word) for each of ac huff table and dc huff table to the Huffman Decoder.

Addresses in bold indicate that locations are accessible by both the ALU and the UPI, otherwise they have UPI access only. Groups of registers that are undirected through CC by the ALU can have a single ALU address specified in the instruction word and CC will select which physical location in the group to access. The ALU address may be that of any of the registers in the group, though conventionally, the address of the first should be used. This is also the case for multi-byte locations which should be accessed using the lowest address of the pair, although in practice, either address will suffice. Note that locations 2E and 2F are accessible in the top-level address map (denoted "T"), i.e., not only through the keyhole registers. These two locations are also reset to zero.

The register file is physically partitioned into four "banks" to improve access speed, but this does not affect

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the addressing in any way. The main table shows allocations for MPEG, and the two repeated sections give the variations for JPEG and H.261 respectively.

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|     | Addr | Location          |     | Addr | Location        |      |
|-----|------|-------------------|-----|------|-----------------|------|
|     | 00   | A register 1      | I   | 3E   | c2              |      |
|     | 01   | A register 0      | I   | 3F   | c3              |      |
|     | 02   | run               | I,O | 40   | dc pred_0 1     |      |
|     | 10   | horiz pels 1      | I,O | 41   | dc pred_0 0     |      |
|     | 11   | horiz pels 0      | I,O | 42   | dc pred_1 1     |      |
|     | 12   | vert pels 1       | I,O | 43   | dc pred_1 0     |      |
|     | 13   | vert pels 0       | I,O | 44   | dc pred_2 1     |      |
|     | 14   | buff size 1       | I,O | 45   | dc pred_2 0     |      |
|     | 15   | buff size 0       | I,O | 46   | dc pred_3 1     |      |
|     | 16   | pel asp. ratio    | I,O | 47   | dc pred_3 0     |      |
|     | 17   | bit rate 2        | O   | 50   | prev mhf 1      |      |
|     | 18   | bit rate 1        | O   | 51   | prev mhf 0      |      |
|     | 19   | bit rate 0        | O   | 52   | prev mvf 1      |      |
|     | 1A   | pic rate          | O   | 53   | prev mvf 0      |      |
|     | 1B   | constrained       | O   | 54   | prev mhb 1      |      |
|     | 1C   | picture type      | O   | 55   | prev mnb 0      |      |
|     | 1D   | H261 picture type | O   | 56   | prev mvb 1      |      |
|     | 1E   | broken closed     | O   | 57   | prev mvb 0      |      |
|     | 1F   | pred mode         | M   | 60   | mb horiz cnt1   | C:3  |
|     | 20   | vbv delay 1       | M   | 61   | mb horiz cnt0   | *    |
|     | 21   | vbv delay 0       | M   | 62   | mb vert cnt1    | C:3  |
|     | 22   | full pel fwd      | M   | 63   | mb vert cnt0    | *    |
|     | 23   | full pel bwd      | M   | 64   | horiz mb 1      |      |
|     | 24   | horiz mb copy     | M   | 65   | horiz mb 0      |      |
|     | 25   | pic number        | M   | 66   | vert mb 1       |      |
|     | 26   | max h             | M   | 67   | vert mb 0       |      |
|     | 27   | max v             | M   | 68   | restart count1  | C:16 |
|     | 28   | -                 | M   | 69   | restart count0  | *    |
|     | 29   | -                 | M   | 6A   | restart gap1    |      |
|     | 2A   | -                 | M   | 6B   | restart gap0    |      |
|     | 2B   | -                 | M   | 6C   | horiz blk count | C:2  |
|     | 2C   | first group       | M   | 6D   | vert blk count  | C:2  |
|     | 2D   | in picture        | H,M | 6E   | comp id         | C:2  |
| T,R | 2E   | rom control       | M   | 6F   | max comp id     |      |
| T,R | 2F   | rom revision      | H,R | 70   | coding sid      |      |
| I,H | 30   | dc huff 0         | M,H | 71   | pattern code    | SR8  |
| I   | 31   | dc huff 1         | H   | 72   | fwd r size      |      |
| I   | 32   | dc huff 2         | H   | 73   | bwd r size      |      |
| I   | 33   | dc huff 3         |     |      |                 |      |
| I,H | 34   | ac huff 0         |     |      |                 |      |
| I   | 35   | ac huff 1         |     |      |                 |      |
| I   | 36   | ac huff 2         | M,I | 78   | h0              |      |

Table B.3.1 Table 1: Huffman Register File Address Map

|   |    |           |  |     |    |    |  |  |
|---|----|-----------|--|-----|----|----|--|--|
| I | 37 | ac huff 3 |  | M,I | 79 | h1 |  |  |
| I | 38 | lq0       |  | M,I | 7A | h2 |  |  |
| I | 39 | lq1       |  | M,I | 7B | h3 |  |  |
| I | 3A | lq2       |  | M,I | 7C | v0 |  |  |
| I | 3B | lq3       |  | M,I | 7D | v1 |  |  |
| I | 3C | c0        |  | M,I | 7E | v2 |  |  |
| I | 3D | c1        |  | M,I | 7F | v3 |  |  |

Table B.3.1 Table 1: Huffman Register File Address Map  
JPEG Variations:

|  |    |                   |  |
|--|----|-------------------|--|
|  | 10 | horiz pels 1      |  |
|  | 11 | horiz pels 0      |  |
|  | 12 | vert pels 1       |  |
|  | 13 | vert pels 0       |  |
|  | 14 | buff size 1       |  |
|  | 15 | buff size 0       |  |
|  | 16 | pel asp. ratio    |  |
|  | 17 | bit rate 2        |  |
|  | 18 | bit rate 1        |  |
|  | 19 | bit rate 0        |  |
|  | 1A | pic rate          |  |
|  | 1B | constrained       |  |
|  | 1C | picture type      |  |
|  | 1D | H261 picture type |  |
|  | 1E | broken closed     |  |
|  | 1F | pred mode         |  |
|  | 20 | vbv delay 1       |  |
|  | 21 | vbv delay 0       |  |
|  | 22 | pending frame ch  |  |
|  | 23 | restart index     |  |
|  | 24 | horiz mb copy     |  |
|  | 25 | pic number        |  |
|  | 26 | max h             |  |
|  | 27 | max v             |  |
|  | 28 | -                 |  |
|  | 29 | -                 |  |
|  | 2A | -                 |  |

Table B.3.2 JPEG Variations

|    |              |  |
|----|--------------|--|
| 2B | -            |  |
| 2C | first scan   |  |
| 2D | in picture   |  |
| 2E | rom control  |  |
| 2F | rom revision |  |

Table B.3.2 JPEG Variations

## H.261 Variations

|    |                   |  |
|----|-------------------|--|
| 10 | horiz pels 1      |  |
| 11 | horiz pels 0      |  |
| 12 | vert pels 1       |  |
| 13 | vert pels 0       |  |
| 14 | buff size 1       |  |
| 15 | buff size 0       |  |
| 16 | pel asp. ratio    |  |
| 17 | bit rate 2        |  |
| 18 | bit rate 1        |  |
| 19 | bit rate 0        |  |
| 1A | pic rate          |  |
| 1B | constrained       |  |
| 1C | picture type      |  |
| 1D | H261 picture type |  |
| 1E | broken closed     |  |
| 1F | pred mode         |  |
| 20 | vvv delay 1       |  |
| 21 | vvv delay 0       |  |
| 22 | full pel fwd      |  |
| 23 | full pel bwd      |  |
| 24 | horiz mb copy     |  |
| 25 | pic number        |  |
| 26 | max h             |  |
| 27 | max v             |  |
| 28 | -                 |  |
| 29 | -                 |  |
| 2A | -                 |  |
| 2B | in gob            |  |

Table B.3.3 H261 Variations

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|  |    |              |  |
|--|----|--------------|--|
|  | 2C | first group  |  |
|  | 2D | in picture   |  |
|  | 2E | rom control  |  |
|  | 2F | rom revision |  |

Table B.3.3 H.261 Variations

## B.3.7 The Microinstruction Word

The ALU microinstruction word, in accordance with the present invention, is split into a number of fields, each controlling a different aspect of the structure described above. The total number of bits used in the instruction word is 36, (plus 1 for the extension bit input) and a minimum of encoding across fields has been adopted so that maximum flexibility of hardware configuration is maintained. The instruction word is partitioned as detailed below. The default field values, that is, those which do not alter the state of the ALU or register file, are those given in the *italics*.

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| Field         | Value   | Description                                  | Bits   |
|---------------|---------|----------------------------------------------|--------|
| OUTSRC        | RSA6    | run, sign, A register as 6 bits              | 0000   |
| (specifies    | ZZA     | zero, zero, A register                       | 0001   |
| sources for   | ZZA8    | zero, zero, A register ls 8 bits             | 0010   |
| run, sign and | ZZADDU4 | zero, zero, adder o/p ms 4 bits              | 0011   |
| level output) | ZINPUT  | zero, input data                             | 0100   |
|               | RSSGX   | run, sign, sign extend o/p                   | 0111   |
|               | RSADD   | run, sign, adder o/p                         | 1000   |
|               | RZADD   | run, zero, adder o/p                         | 1001   |
|               | RIZADD  | input run, zero, adder output                |        |
|               | ZSADD   | zero, sign, adder o/p                        | 1010   |
|               | ZZADD   | zero, zero, adder o/p                        | 1011   |
|               | NONE    | no valid output - out_valid set to zero      | 11XX   |
| REGADDR       | 00 - 7F | register file address for ALU access         | 7 bits |
| REGSRC        | ADD     | drive adder o/p onto register file i/p       | 0      |
|               | SGX     | drive sign extend o/p onto register file i/p | 1      |
| REGMODE       | READ    | read from register file                      | 0      |
|               | WRITE   | write to register file                       | 1      |
| CNGDET        | TEST    | update change detect if REGMODE is WRITE     | 0      |
| (change       | HOLD    | do not update change detect bit              | 1      |
| detect)       | CLEAR   | reset change detect if REGMODE is READ       | 0      |

**Table B.3.4 Table 2: Huffman ALU  
microinstruction fields**



|               |         |                                               |     |
|---------------|---------|-----------------------------------------------|-----|
| RUNSRC        | RUNIN   | drive run i/p onto run register i/p           | 0   |
| (run source)  | ADD     | drive adder o/p onto run register i/p         | 1   |
| RUNMODE       | LOAD    | update run register                           | 0   |
|               | HOLD    | do not update run register                    | 1   |
| ASRC          | ADD     | drive adder o/p onto A register i/p           | 00  |
| (A register   | INPUT   | drive input data onto A register i/p          | 01  |
| source)       | SGX     | drive sign extend o/p onto A register i/p     | 10  |
|               | REG     | drive register file o/p onto A register i/p   | 11  |
| AMODE         | LOAD    | update A register                             | 0   |
|               | HOLD    | do not update A register                      | 1   |
| SGXMODE       | NORMAL  | sign extend with sign                         | 00  |
| (sign extend  | INVERSE | sign extend with -sign                        | 01  |
| mode - see    | DIFMAG  | invert lower bits if sign bit is 0            | 10  |
| section 4)    | DIFCOMP | sign extend with -sign from next bit up       | 11  |
| SIZESRC       | CONST   | drive const. i/p onto sign extend size i/p    | 00  |
| (source for   | A       | drive A register onto sign extend size i/p    | 01  |
| sign extend   | REG     | drive reg. file o/p onto sign extend size i/p | 10  |
| size input)   | RUN     | drive run reg. onto sign extend size i/p      | 11  |
| SGXSRC        | INPUT   | drive input data onto sign extend data i/p    | 0   |
| (sgx input)   | A       | drive A register onto sign extend data i/p    | 1   |
| ADDMODE       | ADD     | input1 + input2                               | 000 |
| (adder mode   | ADC     | input1 + input2 + 1                           | 001 |
| see sect. 3)  | SBC     | input1 - input2 - 1                           | 010 |
|               | SUB     | input1 - input2                               | 011 |
|               | TCI     | SUB if input2 < 0, else ADD - 2's comp.       | 100 |
|               | DCD     | ADC if input2 < 0, else ADD - DC diff         | 101 |
|               | VRA     | ADC if input1 < 0, else SBC-vec resid add     | 110 |
| ADDSRC1       | A       | drive A register onto adder input1            | 00  |
| (source for   | REG     | drive register file o/p onto adder i/p1       | 01  |
| adder-i/p 1 - | INPUT   | drive input data onto adder input1            | 10  |
| non-invert)   | ZERO    | drive zero onto adder input1                  | 11  |
| ADDSRC2       | CONST   | drive constant i/p onto adder input2          | 00  |
| (source for   | A       | drive A register onto adder input2            | 01  |
| inverting     | INPUT   | drive input data onto adder input2            | 10  |
| input)        | REG     | drive register file o/p onto adder i/p2       | 11  |
| CNDC-MODE     | TEST    | update condition codes                        | 0   |

Table B.3.4 Table 2: Huffman ALU microinstruction fields

00001001010000000000000000000000

|               |         |                                    |     |
|---------------|---------|------------------------------------|-----|
| (cond. codes) | HOLD    | do not update condition codes      | 1   |
| CNTMODE       | NOCOUNT | do not increment counters          | X00 |
| (mbstructure  | BCINCR  | increment block counter and ripple | 001 |
| count mode)   | CCINCR  | force the component count to incr  | 010 |
|               | RESET   | reset all counters in mb structure | 011 |
|               | DISABLE | disable all counters               | 1XX |
| INSTMODE      | MULTI   | iterate current instr multi times  | 0   |
|               | SINGLE  | single cycle instruction only      | 1   |

Table B.3.4 Table 2: Huffman ALU microinstruction fields

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## SECTION B.4 Buffer Manager

### B.4.1 Introduction

This document describes the purpose, actions and implementation of the Buffer Manager, in accordance with the present invention (bman).

### B.4.2 Overview

The buffer manager provides four addresses for the DRAM interface. These addresses are page addresses in the DRAM. The DRAM interface maintains two FIFOs in the DRAM, the Coded Data Buffer and the Token Data Buffer. Hence, for the four addresses, there is a read and a write address for each buffer.

### B.4.3 Interfaces

The Buffer Manager is connected only to the DRAM interface and to the microprocessor. The microprocessor need only be used for setting up the "Initialization registers" shown in Table B.4.4. The interface with the DRAM interface is the four eighteen bit addresses controlled by a REQuest/ACKnowledge protocol for each address. (Since the Buffer Manager is not in the datapath, the Buffer Manager lacks a two-wire interface.)

Furthermore, the Buffer Manager operates off the DRAM interface clock generator and on the DRAM interface scan chain.

### B.4.4 Address Calculation

The read and write addresses for each buffer are generated from 9 eighteen bit registers:-

- Initialization registers (RW from microprocessor)
  - BASECB - base address of coded data buffer
  - LENGTHCB - maximum size (in pages of coded data buffer
  - BASETB - base address of token data buffer
  - LENGTHTB - maximum size (in pages) of token data buffer
  - LIMIT - size (in pages) of the DRAM.
- Dynamic registers (RO from microprocessor)
  - READCB - coded data buffer read pointer relative to

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**BASECB**

·NUMBERCB - coded data buffer write pointer relative to READCB

5     ·READTB - token data buffer read pointer relative to BASETB

·NUMBERTB - token data buffer write pointer relative to READTB

To calculate addresses:-

readaddr = (BASE + READ) mod LIMIT

10    writeaddr = (((READ + NUMBER) mod LENGTH) + BASE) mod LIMIT

The "mod LIMIT" term is used because a buffer may wrap around DRAM.

**B.4.5 Block Description**

15     In the present invention, and as shown in Figure 127, the Buffer Manager is composed of three top level modules connected in a ring which snooper monitors the DRAM interface connection. The modules are **bmprtize** (prioritize), **bminstr** (instruction), and **bmrecalc** (recalculate) are arranged in a ring of that order and **omsnoop** (snoopers) is arranged on the address outputs. The module, **Bmprtize**, deals with the REQ/ACK protocol, the FULL/EMPTY flags for the buffers and it maintains the state of each address, i.e., "is it a valid address?". From this information, it dictates to

20     **bminstr** which (if any) address should be recalculated. It also operates the BUF\_CSR (status) microprocessor register, showing FULL/EMPTY flags, and the buf\_access microprocessor register, controlling microprocessor write access to the buffer manager registers.

30     The module, **Bminstr**, on being told by **bmprtize** to calculate an address, issues six instructions (one every two cycles) to control **bmrecalc** to calculating an address.

35     The module, **Bmrecalc**, recalculates the addresses under the instruction of **bminstr**. Running an instruction every two cycles, it contains all of the initialization and dynamic registers, and a simple ALU capable of addition, subtraction and modulus. It informs **sbmprtize** of FULL/EMPTY

states it detects and when it has finished calculating an address.

#### **B.4.6 Block Implementation**

##### **B.4.6.1 Bmptize**

5       At reset, the buf\_access microprocessor register is set to one to allow the setting up of the initialization registers. While buf\_access reads back one, no address calculations are initiated because they are meaningless without valid initialization registers.

10       Once buf\_access is de-asserted (write zero to it) bmptize goes about making all the addresses valid (by recalculating them) since its purpose is to keep all four addresses valid. At this stage, the Buffer Manager is "starting up" (i.e., all addresses have not yet been calculated), thus,  
15       no requests are asserted. Once all addresses have become valid start-up ends and all requests are asserted. From this point forward, when an address becomes invalid (because it has been used and acknowledged) it will be recalculated.

20       No prioritizing between addresses will ever need to be performed, because the DRAM interface can, at its fastest, use an address every seventeen cycles, while the Buffer Manager can recalculate an address every twelve cycles. Therefore, only one address will ever be invalid at one  
25       time after start-up. Accordingly, bmptize will recalculate any invalid address that is not currently being calculated.

      In the invention, start-up will be re-entered whenever buf\_access is asserted and, therefore, no addresses will be supplied to the DRAM interface during microprocessor  
30       accesses.

##### **B.4.6.2 Bminstr**

      The module, Bminstr, contains a MOD 12 cycle counter (the number of cycle it takes to generate an address). Note that even cycles start an instruction, whereas odd cycles  
35       end an instruction. The top 3 bits along with whether it is a read or a write calculation are decoded into instructions for bmrecalc as follows:

00000100 00000000

For read addresses:

| Cycle | Operation | BusA   | BusB   | Result  | Meaning of<br>result's sign |
|-------|-----------|--------|--------|---------|-----------------------------|
| 0-1   | ADD       | READ   | BASE   |         |                             |
| 2-3   | MOD       | Accum  | LIMIT  | Address |                             |
| 4-5   | ADD       | READ   | "1"    |         |                             |
| 6-7   | MOD       | Accum  | LENGTH | READ    |                             |
| 8-9   | SUB       | NUMBER | "1"    | NUMBER  |                             |
| 10-11 | MOD       | "0"    | Accum  |         | SET_EMPTY<br>(NUMBER >= 0)  |

Table B.4.1 Read address calculation

For write addresses:

| Cycle | Operation | BusA   | BusB   | Result  | Meaning of<br>result's sign       |
|-------|-----------|--------|--------|---------|-----------------------------------|
| 0-1   | ADD       | NUMBER | READ   |         |                                   |
| 2-3   | MOD       | Accum  | LIMIT  |         |                                   |
| 4-5   | ADD       | Accum  | BASE   |         |                                   |
| 6-7   | MOD       | Accum  | LIMIT  | Address |                                   |
| 8-9   | ADD       | NUMBER | "1"    | NUMBER  |                                   |
| 10-11 | MOD       | Accum  | LENGTH |         | SET_FULL<br>(NUMBER<br>>= LENGTH) |

Table B.4.2 For write address calculations

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Note: The result of the last operation is always held in the accumulator.

When there is no addresses to be recalculated, the cycle counter idles at zero, thus causing an instruction that writes to none of the registers. This has no affect.

#### B.4.6.3 Bmrecalc

The module, Bmrecalc, performs one operation every two clock cycles. It latches in the instruction from bminstr (and which buffer and io type) on an even counter cycle (start\_alu\_cyc), and latches the result of the operation on an odd counter cycle (end\_alu\_cyc). The result of the operation is always stored in the "Accum" register in addition to any registers specified by the instruction. Also, on end\_alu\_cyc, bmrecalc informs bmprtize as to whether the use of the address just calculated will make the buffer full or empty, and when the address and full/empty has been successfully calculated (load\_addr).

Full/empty are calculated using the sign bit of the operation's result.

The modulus operation is not a true modulus, but  $A \bmod B$  is implemented as:

$(A > B ? (A - B) : A)$

however this is only wrong when

$A > (2B - 1)$

which will never occur.

#### B.4.6.4 Bmsnoop

The module, Bmsnoop, is composed of four eighteen bit super snoopers that monitor the addresses supplied to the DRAM interface. The snoopers must be "super" (i.e., can be accessed with the clocks running) to allow on chip testing of the external DRAM. These snoopers must work on a REQ/ACK system and are, therefore, different to any other on the device.

REQ/ACK is used on this interface, as opposed to a two-wire protocol because it is essential to transmit information (i.e., acknowledges) back to the sender which an accept will not do). Hence, this rigorously monitors

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the FIFO pointers.

To gain microprocessor write access to the initialization registers, a one should be written to buf\_access, and access will be given when buf\_access reads back one. Conversely, to give up microprocessor write access, zero should be written to buf\_access. Access will be given when buf\_access reads back zero. Note that buf\_access is reset to one.

It is intended that the initialization registers be  
15 written to only once. Re-writing them may cause the  
buffers to operate incorrectly. However, it is envisioned  
to increase the buffer length on-the-fly and to have the  
buffer manager use the new length when appropriate.



| Register Name        | Usage    | Address |
|----------------------|----------|---------|
| CED_BUF_ACCESS       | xxxxxxD  | 0x24    |
| CED_BUF_KEYHOLE_ADDR | x0000000 | 0x25    |
| CED_BUF_KEYHOLE      | 00000000 | 0x26    |
| CED_BUF_CB_WR_SNP_2  | xxxxxxDD | 0x54    |
| CED_BUF_CB_WR_SNP_1  | DDDDDDDD | 0x55    |
| CED_BUF_CB_WR_SNP_0  | DDDDDDDD | 0x56    |
| CED_BUF_CB_RD_SNP_2  | xxxxxxDD | 0x57    |
| CED_BUF_CB_RD_SNP_1  | DDDDDDDD | 0x58    |
| CED_BUF_CB_RD_SNP_0  | DDDDDDDD | 0x59    |
| CED_BUF_TB_WR_SNP_2  | xxxxxxDD | 0x5a    |
| CED_BUF_TB_WR_SNP_1  | DDDDDDDD | 0x5b    |
| CED_BUF_TB_WR_SNP_0  | DDDDDDDD | 0x5c    |
| CED_BUF_TB_RD_SNP_2  | xxxxxxDD | 0x5d    |
| CED_BUF_TB_RD_SNP_1  | DDDDDDDD | 0x5e    |
| CED_BUF_TB_RD_SNP_0  | DDDDDDDD | 0x5f    |

Table B.4.3 Buffer manager non-keyhole registers

Where D indicates a registers bit and x shows no register bit.

| Keyhole Register Name | Usage    | Key hole Address |
|-----------------------|----------|------------------|
| CED_BUF_CB_BASE_3     | xxxxxxxx | 0x00             |
| CED_BUF_CB_BASE_2     | xxxxxxDD | 0x01             |
| CED_BUF_CB_BASE_1     | DDDDDDDD | 0x02             |
| CED_BUF_CB_BASE_0     | DDDDDDDD | 0x03             |
| CED_BUF_CB_LENGTH_3   | xxxxxxxx | 0x04             |
| CED_BUF_CB_LENGTH_2   | xxxxxxDD | 0x05             |
| CED_BUF_CB_LENGTH_1   | DDDDDDDD | 0x06             |
| CED_BUF_CB_LENGTH_0   | DDDDDDDD | 0x07             |
| CED_BUF_CB_READ_3     | xxxxxxxx | 0x08             |
| CED_BUF_CB_READ_2     | xxxxxxDD | 0x09             |
| CED_BUF_CB_READ_1     | DDDDDDDD | 0x0a             |
| CED_BUF_CB_READ_0     | DDDDDDDD | 0x0b             |
| CED_BUF_CB_NUMBER_3   | xxxxxxxx | 0x0c             |

Table B.4.4 Registers in buffer manager keyhole

| Keyhole Register Name | Usage    | Key hole Address |
|-----------------------|----------|------------------|
| CED_BUF_CB_NUMBER_2   | xxxxxxDD | 0x0d             |
| CED_BUF_CB_NUMBER_1   | DDDDDDDD | 0x0e             |
| CED_BUF_CB_NUMBER_0   | DDDDDDDD | 0x0f             |
| CED_BUF_TB_BASE_3     | xxxxxxxx | 0x10             |
| CED_BUF_TB_BASE_2     | xxxxxxDD | 0x11             |
| CED_BUF_TB_BASE_1     | DDDDDDDD | 0x12             |
| CED_BUF_TB_BASE_0     | DDDDDDDD | 0x13             |
| CED_BUF_TB_LENGTH_3   | xxxxxxxx | 0x14             |
| CED_BUF_TB_LENGTH_2   | xxxxxxDD | 0x15             |
| CED_BUF_TB_LENGTH_1   | DDDDDDDD | 0x16             |
| CED_BUF_TB_LENGTH_0   | DDDDDDDD | 0x17             |
| CED_BUF_TB_READ_3     | xxxxxxxx | 0x18             |
| CED_BUF_TB_READ_2     | xxxxxxDD | 0x19             |
| CED_BUF_TB_READ_1     | DDDDDDDD | 0x1a             |
| CED_BUF_TB_READ_0     | DDDDDDDD | 0x1b             |
| CED_BUF_TB_NUMBER_3   | xxxxxxxx | 0x1c             |
| CED_BUF_TB_NUMBER_2   | xxxxxxDD | 0x1d             |
| CED_BUF_TB_NUMBER_1   | DDDDDDDD | 0x1e             |
| CED_BUF_TB_NUMBER_0   | DDDDDDDD | 0x1f             |
| CED_BUF_LIMIT_3       | xxxxxxxx | 0x20             |
| CED_BUF_LIMIT_2       | xxxxxxDD | 0x21             |
| CED_BUF_LIMIT_1       | DDDDDDDD | 0x22             |
| CED_BUF_LIMIT_0       | DDDDDDDD | 0x23             |
| CED_BUF_CSR           | xxxxDDDD | 0x24             |

Table B.4.4 Registers in buffer manager keyhole

#### B.4.8 Verification

Verification was conducted in Lsim with small FIFO's onto a dummy DRAM interface, and in C-code as part of the top level chip simulation.

**B.4.9 Testing**

Test coverage to the `bman` is through the snoopers in `bmsnoop`, the dynamic registers (shown in B.4.4) and using the scan chain which is part of the DRAM interface scan chain.

00000000-00000000



Output is an 11 bit token port. All interfaces are controlled by the two-wire interface protocol. Imodel has its own clock generator and scan chain.

Both blocks have microprocessor access only to the snoopers at their outputs.

#### B.5.4 Block description

##### B.5.4.1 Hsppk

Hsppk takes in the 17 bit data from the Huffman and outputs 16 bit data to the Token buffer. This is achieved by first, either truncating or splitting the input data into 12 bit words, and second by packing these words into a 16 bit format.

##### B.5.4.1.1 Splitting

Hsppk receives 17 bit data from the Inverse Huffman. This data is formatted into 12 bits using the following formats.

Where F = specifies format; E = extension bit; R = Run bit; L = length bit (in sign mag.) or non-DATA token bit; x = don't care.

FLLLLLLLLLLLLLFormat 0  
ELLLLLLLLLLLLLFormat 0a

FRRRRRR00000Format 1

Normal tokens only occupy the bottom 12 bits, having the form:

ExxxxxxLLLLLLLLLLLL

This is truncated to format 0a

However, DATA tokens have a run and a level in each word in the form:

ERRRRRRLLLLLLLLLLLL.

This is broken in to the formats:

ERRRRRRLLLLLLLLLLLL->FRRRRRR00000Format 1

ELLLLLLLLLLLLLFormat 0a

Or if the run is zero format 0 is used:

E000000LLLLLLLLLLLL->FLLLLLLLLLLLLLFormat 0

It can be seen that in the format 0, the extension bit is lost and assumed to be one. Therefore, it cannot be used where the extension is zero. In this case, format 1 is

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unconditionally used.

#### B.5.4.1.2 Packing

After splitting, all data words are 12 bits wide. Every four 12 bit words are "packed" into three 16 bit words:

| Input words  | Output words    |
|--------------|-----------------|
| 000000000000 | 000000000001111 |
| 111111111111 | 111111122222222 |
| 222222222222 | 222233333333333 |
| 333333333333 |                 |

Table B.5.1 Packing method

#### B.5.4.1.3 Flushing of the buffer

The DRAM interface of the present invention collects a block, 32 sixteen bit "packed" words, before writing them to the buffer. This implies that data can get stuck in the DRAM interface at the end of a stream, if the block is only partially complete. Therefore a flushing mechanism is required. Accordingly, `.Hsppk` signals the DRAM interface to write its current partially complete block unconditionally.

#### B.5.4.2.1 Imup (UnPacker)

Imup performs three functions:

4) Unpacking data from its sixteen bit format into 12 bit words.

| Input words     | Output words |
|-----------------|--------------|
| 000000000001111 | 000000000000 |
| 111111122222222 | 111111111111 |
| 222233333333333 | 222222222222 |
|                 | 333333333333 |

Table B.5.2 Unpacking method

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When the DRAM interface flushes, by unconditionally writing the current partially complete block, rubbish data remains in the block. The imup must delete rubbish data, i.e., delete all data from a FLUSH token, until the end of a block.

Output of data from the block is conditional that a  
10 "valid" (stream\_enable) is accepted from the Buffer Start-  
up for each different stream. Consequently, twelve bit  
data is output to hspbk.

In the invention, `inex` expands out all run length codes  
15 into runs of zeros followed by a level.

Impad ensures that all DATA Token bodies contain 64 (or more) words. It does this by padding the last word of the Token with zeros. DATA Tokens are not checked for having over 64 words in the body.

#### B.5.5.1 Hsppk

25 B.5.5.1.1 Splitting

IF (datatoken)

```
ELSE IF (run == 0) use format 0;
```

```
ELSE use format 0a;
```

```
format 0 format bit = 0;
```

```
35  format 1 format bit = 1;
```

If format 1 is used, no new data should be accepted in the next cycle because the level of the code has yet to be

output.

#### B.5.5.1.2 Packing

The packing procedure cycles every four valid data inputs. The sixteen bit word output is formed from the last valid word, which is held, and the succeeding word. If this is not valid, then the output is not valid. The procedure is:

|               | Held Word    | Succeeding Word | Packed Word      |              |
|---------------|--------------|-----------------|------------------|--------------|
| valid cycle 0 | xxxxxxxxxxx  | 000000000000    | xxxxxxxxxxxxxxxx | don't output |
| valid cycle 1 | 000000000000 | 111111111111    | 0000000000001111 | output       |
| valid cycle 2 | 111111111111 | 222222222222    | 1111111122222222 | output       |
| valid cycle 3 | 222222222222 | 333333333333    | 2222333333333333 | output       |

**Table B.5.3 Packing procedure**

Where x indicates undefined bits.

10 During valid cycle 0, no word is output because it is not valid.

The valid cycle number is maintained by a ring counter. It is incremented by valid data from the splitter and an accepted output.

15 When a FLUSH (or picture\_end) token is received and the token itself is ready to output, a flush signal is also output to the DRAM interface to reset the valid cycle to zero. If a FLUSH token arrives on anything but cycle 3, the flush signal must be delayed a valid cycle to ensure  
20 the token itself is output.

#### B.5.5.2 Imodel

##### B5.5.2.1 Imup (Unpacker)

As with the packer, the last valid input is stored, and combined with the next input, allows unpacking.



**FOI b6**

**FOI b6**

**FOI b6**

**FOI b6**

**FOI b6**

[illegible]

**FOI b6**

**FOI b6**  
**b7C**

- [illegible]

[illegible][illegible]



### B.5.6 Registers

The *imodel* and *hsppk* of the present invention do not have microprocessor registers, with the exception of their snoopers.

| Register Name | Usage                 | Address |
|---------------|-----------------------|---------|
| CED_H_SNP_2   | VAXxxxxx              | 0x49    |
| CED_H_SNP_1   | DDDDDDDD              | 0x4a    |
| CED_H_SNP_0   | DDDDDDDD              | 0x4b    |
| CED_IM_SNP_1  | VAE <del>xx</del> DDD | 0x4a    |
| CED_IM_SNP_0  | DDDDDDDD              | 0x4d    |

Table B.5.5 *Imodel* & *hsppk* registers

Where V = valid bit; A = accept bit; E = extension bit; D = data bit.

### B.5.7 Verification

Selected streams run through Lsim simulations.

### B.5.8 Testing

Test coverage to the *imodel* at the input is through the Token buffer output snoopers, and at the output through the *imodel*'s own snoopers. Logic is covered the *imodel*'s own scan chain.

The output of the *hsppk* is accessible through the huffman output snoopers. The logic is visible through the huffman scan chain.

## SECTION B.6 Buffer Start-up

### B.6.1 Introduction

This section describes the method and implementation of the buffer start-up in accordance with the present invention.

### B.6.2 Overview

To ensure that a stream of pictures can be displayed smoothly and continuously a certain amount of data must be gathered before decoding can start. This is called the start-up condition. The coding standard specifies a VBV delay which can be translated, approximately, into the amount of data needed to be gathered. It is the purpose of the "Buffer Start-up" to ensure that every stream fulfills its start-up condition before its data progresses from the token buffer, allowing decoding. It is held in the buffers by a notional gate (the output gate) at the output of the token buffer (i.e., in the Inverse Modeler). This gate will only be open for the stream once its start-up condition has been met.

### B.6.3 Interfaces

**Bscntbit** (Buffer Start-up bit counter) is in the datapath, and communicates by two-wire interfaces, and is connected to the microprocessor. It also branches with a two-wire interface to **bsogl** (Buffer Start-up Output Gate Logic). **bsogl** via a two-wire interface controls **imup** (Inverse Modeler UnPacker), which implements the output gate.

### B.6.4 Block Structure

As shown in Figure 130, **Bscntbit** lies in the datapath between the Start Code Detector and the coded data buffer. This single cycle block counts the valid words of data leaving the block and compares this number with the start-up condition (or target) which will be loaded from the microprocessor. When the target is met, **bsogl** is informed. Data is unaffected by **bscntbit**.

**bsogl** lies between **bscntbit** and **imup** (in the inverse modeler). In effect, it is a queue of indicators that streams have met their targets. The queue is moved along

by streams leaving the buffers (i.e., FLUSH tokens received in the data stream at `imup`), when another "indicator" is accepted by `imup`. If the queue is empty (i.e., there are no streams in the buffers which have yet met their start-up target) the stream in `imup` is stalled.

The queue only has a finite depth, however, this may be indefinitely expanded by breaking the queue in `bsogl` and allowing the microprocessor to monitor the queue. These queue mechanisms are referred to as internal and external queues respectively.

### B.6.5 Block Implementation

The comparison (`ced_bs_count >=ced_bs_target`) is done by `bscmp`.

The target is derived from the stream when the stream is in the Huffman Decoder and calculated by the microprocessor. It will, therefore, only be set sometime after the start of the stream. Before start-up, the target\_valid is set low. Writing to ced\_bs\_target sets target\_valid high and allows comparisons in bscmp to take place. When the comparison shows ced\_bs\_count >= ced\_bs\_target, target\_valid is set low. The target has been met.

When the target is met the count is reset. Note, it is not reset at the end of a stream. In addition, counting is disabled after the target is met if it is before the end of the stream. The count saturates to 255.

When a stream ends (i.e., a flush) is detected in

`bsbitcnt`, an `abs_flush_event` is generated. If the stream ends before the target is met, an additional event is also generated (`bs_flush_before_target_met_event`). When any of these events occur, the block is stalled. This allows the user to recommence the search for the next stream's target or in the case of a `bs_flush_before_target_met_event` event either:

- 1) write a target of zero which will force a `target_met` or
- 2) note that target was not met and allow the next stream to proceed until this combined with the last stream reaches the target. The target for this next stream can should adjusted accordingly.

#### **B.6.5.2 BSOGL (buffer start-up output gate logic)**

As previously described, `bsogl` is a queue of indicators that a stream has met its target. The queue type is set by `ced_bs_queue` (`internal(0)` or `external(1)`). This is a reset to select an internal queue. The depth of the queue determines the maximum number of satisfied streams that can be in the coded data buffer, Huffman, and token buffer. When this number is reached (i.e. the queue is full) `bsogl` will force the datapath to stall at `bsbitcnt`.

Using an internal queue requires no action from the microprocessor. However, if it is necessary to increase the depth of the queue, an external queue can be set (by setting `ced_bs_access` to gain access to `ced_bs_queue` which should be set, `target_met_event` and `stream_end_event` enabled and access relinquished).

The external queue (a count maintained by the microprocessor) is inserted into the internal queue. The external queue is maintained by two events. `target_met_event` and `stream_end_event`. These can simply be referred to as `service_queue_input` and `service_queue_output` respectively] and a register `ced_bs_enable_nxt_stream`. In effect, `target_met_event` is the up stream end of the internal queue supplying the queue. Similarly, `ced_bs_enable_nxt_stream` is the down stream end of the

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The queue type can be changed from internal to external at any time (by the means described above), but they can only be changed external to internal when the external queue is empty (from above "queue==0"), by setting  
5 ced\_bs\_access to gain access to ced\_bs\_queue which should be reset, target\_met\_event and stream\_end\_event masked, and access relinquished.

On the other hand, disable checking of stream start-up conditions, set ced\_bs\_queue (external), mask  
10 target\_met\_event and stream\_end\_event and set ced\_bs\_enable\_nxt\_stream. In this way, all streams will always be enabled.

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### B.6.6 Microprocessor registers

| Register name                        | Usage     | Address |
|--------------------------------------|-----------|---------|
| CED_BS_ACCESS                        | xxxxxxxxD | 0x10    |
| CED_BS_PRESCALE*                     | xxxxxDDD  | 0x11    |
| CED_BS_TARGET*                       | DDDDDDDDD | 0x12    |
| CED_BS_COUNT*                        | DDDDDDDDD | 0x13    |
| BS_FLUSH_EVENT                       | ffffDfff  | 0x02    |
| BS_FLUSH_MASK                        | ffffDfff  | 0x03    |
| BS_FLUSH_BEFORE_TARGET_ME<br>T_EVENT | ffffDfff  | 0x02    |
| BS_FLUSH_BEFORE_TARGET_ME<br>T_MASK  | ffffDfff  | 0x03    |

Table B.6.1 Bscntbit registers

| Register name    | Usage    | Address |
|------------------|----------|---------|
| TARGET_MET_EVENT | ===D===  | 0x02    |
| TARGET_MET_MASK  | ===D===  | 0x03    |
| STREAM_END_EVENT | ==D===== | 0x02    |
| STREAM_END_MASK  | ==D===== | 0x03    |

Table B.6.2 Bsogl registers

| Register name          | Usage     | Address |
|------------------------|-----------|---------|
| CED_BS_QUEUE*          | xxxxxxxxD | 0x14    |
| CED_BS_ENABLE_NXT_STM* | xxxxxxxxD | 0x15    |

Table 8.6.2 8306 registers

where

·D is a register bit

·x is a non-existent register bit

·r is a reserved register bit

- 5     to gain access to these registers ced\_bs\_access must be set to one and polled until it reads back one, unless in an interrupt service routine. Access is given up by setting ced\_bs\_access to zero.

00000000000000000000000000000000

### B.7.1 Overview

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The following section describes the operation of a DRAM interface in accordance with the present invention, which has one write swing buffer and one read swing buffer, which is essentially the same as the operation of the Spatial Decoder DRAM Interface. This is illustrated in Figure 131, "DRAM Interface,".

Referring to Figure 131, the interfaces to the address generator 420 and to the blocks which supply and take the data are all two wire interfaces. The address generator 420 may either generate addresses as the result of receiving control tokens, or it may merely generate a fixed sequence of addresses. The DRAM interface 421 treats the two wire interfaces associated with the address generator in a special way. Instead of keeping the accept line high when it is ready to receive an address, it waits for the address generator to supply a valid address, processes that address and then sets the accept line high for one clock period. Thus, it implements a request/acknowledge (REQ/ACK) protocol.

In understanding the operation of the DRAM Interface of the present invention, it is important to note that in a

5 Each DRAM Interface contains a method of determining which swing buffer it will service next. In general, this will be either a "round robin", in which the swing buffer which is serviced is the next available swing buffer which has less recently had a turn, or a priority encoder in  
10 which some swing buffers have a higher priority than others. In both cases, an additional request will come from a refresh request generator which has a higher priority than all the other requests. The refresh request is generated from a refresh counter which can be programmed  
15 via the microprocessor interface.

Figure 132 illustrates a write swing buffer. The operation is as follows:

- 1)Valid data is presented at the input 430 (data in). As each piece of data is accepted it is written into RAM1 and the address is incremented.
- 2)When RAM1 is full, the input side gives up control and sends a signal to the read side to indicate that RAM1 is now ready to be read. This signal passes between two asynchronous clock regimes, and so passes through three synchronizing flip-flops.
- 3)The next item of data to arrive on the input side is written into RAM2, which is still empty.
- 4)When the round robin or priority encoder indicates that it is the turn of this swing buffer to be read, the DRAM Interface reads the contents of RAM1 and writes them to the external DRAM. A signal is then sent back across the asynchronous interface, as in (2), to indicate that RAM1 is now ready to be filled again.
- 5)If the DRAM Interface empties RAM1 and "swings" it before the input side has filled RAM2, then data can



uses timing chains to place the edges of the DRAM signals to a precision of a quarter of the system clock period. Two quadrature clocks from the phase locked loop are used. These are combined to form a notional 2x clock. Any one chain is then made from two shift registers in parallel, on opposite phases of the "2x clock".

First of all, there is one chain for the page start cycle and another for the read/write/refresh cycles. The length of each cycle is programmable via the microprocessor interface, after which the page start chain has a fixed length, and the cycle chain's length changes as appropriate during a page start.

On reset, the chains are cleared and a pulse is created. This pulse travels along the chains, being directed by the state information from the DRAM Interface. The DRAM Interface clock is generated by this pulse. Each DRAM Interface clock period corresponds to one cycle of the DRAM. Thus, as the DRAM cycles have different lengths, the DRAM Interface clock is not at a constant rate.

Further, timing chains combine the pulse from the above chains with the information from DRAM Interface to generate the output strobes and enables (notcas, notras, notwe, notoe).

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### B.8.1 Introduction

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The inverse quantizer reconstructs coefficients from quantized coefficients, quantization weights and step sizes, all of which are transmitted within the datastream.

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#### B.8.4.1 H261 Equations

$$\left. \begin{aligned} \dot{C}_i &= 8Q_i \quad i = 0 \\ \dot{C}_i &= \text{iq\_quant\_scale}[2Q_i + \text{sign}(Q_i)] \\ \dot{C}_i &= \dot{C}_i - \text{sign}(\dot{C}_i) \quad \dot{C}_i = \text{even} \\ \dot{C}_i &= \dot{C}_i \quad \dot{C}_i = \text{odd} \end{aligned} \right\} 0 < i < 64$$

$$C_i = \min(\max(\dot{C}_i, -2048), 2047)$$
$$\left. \begin{aligned} C_i' &= iq\_quant\_scale \{ 2Q_i + sign(Q_i) \} \\ C_i' &= C_i - sign(C_i') \quad C_i' = \text{even} \\ C_i' &= C_i \quad C_i' = \text{odd} \end{aligned} \right\} \quad 0 \leq i < 64$$

$$C_i = \min(\max(C_i', -2048), 2047)$$



#### B.8.4.2 JPEG Equations

$$\hat{C}_i = W_{i,j} Q_i + 1024 \quad i = 0$$

$$\hat{C}_i = W_{i,j} Q_i \quad 0 < i < 64$$

$$C_i = \min(\max(\hat{C}_i, -2048), 2047)$$

$$j = \text{jpeg\_table\_indirection}(c)$$

#### B.8.4.3 MPEG Equations

For blocks coded in intra mode:

$$\hat{C}_i = W_{i,j} Q_i + 1024 \quad i = 0$$

$$\left. \begin{aligned} \hat{C}_i &= \text{floor}\left(\frac{2\text{iq\_quant\_scale}W_{i,j}Q_i}{16}\right) \\ \hat{C}_i &= \hat{C}_i - \text{sign}(\hat{C}_i) \quad \hat{C}_i = \text{even} \\ \hat{C}_i &= \hat{C}_i \quad \hat{C}_i = \text{odd} \end{aligned} \right\} \quad \begin{aligned} 0 < i < 64 \\ j &= 0, 2 \end{aligned}$$

$$C_i = \min(\max(\hat{C}_i, -2048), 2047)$$

1024 is added in intra DC case to account for predictors in huffman being reset to zero.

For all other coded blocks :

$$\left. \begin{aligned} \hat{C}_i &= \text{floor}\left(\frac{\text{iq\_quant\_scale}W_{i,j}(2Q_i + \text{sign}(Q_i))}{16}\right) \\ \hat{C}_i &= \hat{C}_i - \text{sign}(\hat{C}_i) \quad \hat{C}_i = \text{even} \\ \hat{C}_i &= \hat{C}_i \quad \hat{C}_i = \text{odd} \end{aligned} \right\} \quad \begin{aligned} 0 < i < 64 \\ j &= 1, 3 \end{aligned}$$

$$C_i = \min(\max(\hat{C}_i, -2048), 2047)$$

#### B.8.4.4 JPEG Variation Equations

$$\hat{C}_i = \text{floor}\left(\frac{2\text{iq\_quant\_scale}W_{i,j}Q_i}{16}\right) + 1024 \quad i = 0$$

$$\hat{C}_i = \text{floor}\left(\frac{2\text{iq\_quant\_scale}W_{i,j}Q_i}{16}\right) \quad 0 < i < 64$$

$$C_i = \min(\max(\hat{C}_i, -2048), 2047)$$

$$j = \text{jpeg\_table\_indirection}(c)$$

**B.8.4.5 All other tokens**

All tokens except DATA Tokens must pass through the iq unquantized

Where:

$$\begin{aligned} \text{sign}(a) &= \begin{cases} -1 & a < 0 \\ 0 & a = 0 \\ 1 & a > 0 \end{cases} \\ \max(a, b) &= \begin{cases} a & a > b \\ b & a \leq b \end{cases} \\ \min(a, b) &= \begin{cases} a & a \leq b \\ b & a > b \end{cases} \end{aligned}$$

Floor(a) returns an integer such that:

$$\begin{aligned} (a-1) < \text{floor}(a) \leq a & \quad a \geq 0 \\ a \leq \text{floor}(a) < (a+1) & \quad a \leq 0 \end{aligned}$$

$Q_i$  are the quantized coefficients.

$C_i$  are the reconstructed coefficients

$W_{i,j}$  are the values in the quantisation table matrices

$i$  is the coefficient index along the zig-zag

$j$  is the quantisation table matrix number ( $0 \leq j \leq 3$ )

**B.8.4.6 Multiple Standards combined**

It can be shown that all the above standards and their variations (also control data which must be unchanged by the iq) can be mapped on to single equation:

$$\text{OUTPUT} = \frac{(2\text{INPUT} + k)(xy)}{16}$$

With the additional post inverse quantisation functions of :

- Add 1024
- Convert from sign magnitude to 2's complement representation.
- Round all even numbers to the nearest odd number towards zero.
- Saturate result to +2047 or -2048.

The variables  $k$ ,  $x$  and  $y$  for each variation of the standards and which functions they use is shown in Table B.8.1.

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**B.8.4.6 Multiple standards combined**

| Standard     |          | x      | y              | k | Add  | Round | Sat  | Convert  |
|--------------|----------|--------|----------------|---|------|-------|------|----------|
|              |          | Weight | Scale          |   | 1024 | Even  | Post | 2's comp |
| H261         | intra DC | 8      | 8              | 0 | No   | No    | Yes  | Yes      |
|              | intra    | 16     | iq_quant_scale | 1 | No   | Yes   | Yes  | Yes      |
|              | other    | 16     | iq_quant_scale | 1 | No   | Yes   | Yes  | Yes      |
| JPEG         | DC       | $W_i$  | 8              | 0 | Yes  | No    | Yes  | Yes      |
|              | other    | $W_i$  | 8              | 0 | No   | No    | Yes  | Yes      |
| MPEG         | intraDC  | 8      | 8              | 0 | Yes  | No    | Yes  | Yes      |
|              | intra    | $W_i$  | iq_quant_scale | 0 | No   | No    | Yes  | Yes      |
|              | other    | $W_i$  | iq_quant_scale | 1 | No   | Yes   | Yes  | Yes      |
| XXX          | DC       | $W_i$  | iq_quant_scale | 0 | Yes  | No    | Yes  | Yes      |
|              | other    | $W_i$  | iq_quant_scale | 0 | No   | No    | Yes  | Yes      |
| Other Tokens |          | 1      | 8              | 0 | No   | No    | No   | No       |

**Table B.8.1 Control decoding****B.8.5 Block Structure**

From B.8.4.6 and Table B.8.1, it can be seen that a single architecture can be used for a multi-standard inverse quantizer. Its arithmetic block diagram is shown in Fig. 133 "Arithmetic Block":

Control for the arithmetic block can be functionally broken into two sections:

- 10     : Decoding of tokens to load status registers or quantization tables.
- : Decoding of the status registers into control signals.

15     Tokens are decoded in iqca which controls the next cycle, i.e., iqcb's bank of registers. It also controls the access to the four quantization tables in igran. The arithmetic, that is, two multipliers and the post functions, are in iqarith. The complete block diagram for the iq is shown in

Figure 134.

## B.8.6 Block Implementation

### B.8.6.1 Iqca

5 In the invention, *iqca* is a state machine used to decode tokens into control signals for *igram* and the register in *iqcb*. The state machine is better described as a state machine for each token since it is reset by each new token. For example:

10 The code for the QUANT\_SCALE (see B.8.7.4, "QUANT\_SCALE") and QUANT\_TABLE (see B.8.7.6, "QUANT\_TABLE") are as follows:

```

if (tokenheader == QUANT_SCALE)
(
    sprintf(preport, "QUANT_SCALE");
    reg_addr = ADDR_IQ_QUANT_SCALE;
    rnotw = WRITE;
    enable = 1;
)

if (tokenheader == QUANT_TABLE) /*QUANT_TABLE token */
switch (substate)
(
    case 0: /* quantisation table header */
        sprintf(preport, "QUANT_TABLE_%s_s0",
            (headerextn ? "(full)" : "(empty)"));
        nextsubstate = 1;
        insertnext = (headerextn ? 0 : 1);
        reg_addr = ADDR_IQ_COMPONENT;
        rnotw = WRITE;
        enable = 1;

```

```

break;

case 1: /* quantisation table body */
    sprintf(preport, "QUANT_TABLE_%s_s1",
        (headerextn ? "(full)" : "(empty)"));
    nextsubstate = 1;
    insertnext = (headerextn ? 0 : (qtm_addr_63 == 0));
    reg_addr = USE_QTM;
    motw = (headerextn ? WRITE : READ);
    enable = 1;
    break;

default:
    sprintf(preport, "ERROR in iq quantisation table tokendecoder
(substate %x)\n",
        substate);

    break;
}
}

```

Where a substate is a state within a token, QUANT\_SCALE has, for example, only one substate. However, the QUANT\_TABLE has two, one being the header, the second the token body.

10 Additionally, iqca supplies addresses to igram from BodyWord counter and inserts words into the stream, for example in an unextended QUANT\_TABLE (see B.8.7.4). This is achieved by stalling the input while maintaining the output valid. The words can be filled with the correct data in succeeding blocks (iqcb or iqarith).

B.8.6.2 iqcb

20       The status registers are decoded (see Table B.8.1) into control wires for iqarith; to control the XY multiplier terms and the post quantization functions.

30     The status registers are accessible from the microprocessor only when the register `iq_access` has been set to one and reads back one. In this situation, `iqcb` has halted the datapath, thus ensuring the registers have a stable value and no data is corrupted in the datapath.

### B.8.6.3 Iqram

(QTM), each 64\*8 bits. It is, therefore, a 256\*8 bits six transistor RAM, capable of one read or one write per cycle. The RAM is enclosed by two-wire interface logic receiving its control and write data from iqca. It reads out data to  
 5 iqarith. Similarly, igran occupies the same cycle in the datapath as iqcb.

The RAM may be read and written from the microprocessor when iq\_access reads back one. The RAM is placed behind a keyhole register, iq\_qtm\_keyhole and addressed by  
 10 iq\_qtm\_keyhole\_addr. Accessing iq\_qtm\_keyhole will cause the address to which it points, held in iq\_qtm\_keyhole\_addr to be incremented. Likewise, iq\_qtm\_keyhole\_addr can be written to directly.

#### B.8.6.4 iqarith

15 Note, iqarith is three functions pipelined and split over three cycles. The functions are discussed below (see Figure 133).

##### B.8.6.4.1 XY multiplier

20 This is a 5(X) by 8(Y) bit carry save unsigned multiplier feeding on to the datapath multiplier. The multiplier and multiplicand are selected with control wires from iqcb. The multiplication is in the first cycle, the resolving adder in the second.

At the input to the multiplier, data from igran can be  
 25 muxed onto the datapath to read a QUANT\_TABLE out onto the datapath.

##### B.8.6.4.2 (XY)\* datapath multiplier

This 13 (XY) by 12 (datapath) bit carry save unsigned multiplier is split over the three cycles of the block.  
 30 Three partial products in the first cycle, seven in the second and the remaining two in the third.

Since all output from the multiplier is less than 2047 (non\_coefficient) or saturated to +2047/-2048, the top twelve bits don't ever need to be resolved. Accordingly,  
 35 the resolving adder is just two bits wide. On the remainder of the high order bits, a zero detect suffices as a saturate signal.

**B.8.6.4.3 Post quantization functions**

The post quantization functions are

- Add 1024
- Convert from sign magnitude to 2's complement representation.
- Round all even numbers to the nearest odd number towards zero.
- Saturate result to +2047 or -2048.
- Set output to zero (see B.8.6.2)

The first three functions are implemented on a 12 bit adder (pipelined over the second and third cycles). From this, it can be seen what each function requires and these are then combined onto the single adder.

| Function                  | if datapath > 0 | if datapath > 0 |
|---------------------------|-----------------|-----------------|
| Convert to 2's complement | nothing         | invert add one  |
| Round all even numbers    | subtract one    | add one         |

| Function | - if datapath > 0 | if datapath > 0 |
|----------|-------------------|-----------------|
| Add 1024 | add 1024          | add 1024        |

**Table B.8.2 Post quantization adder functions**

As will be appreciated by one of ordinary skill in the art, care should be taken when reprogramming these functions as they are very interdependent when combined.

The saturate values, zero and zero+1024 are muxed onto the datapath at the end of the third cycle.

**B.8.7 Inverse Quantizer Tokens**

The following notes define the behavior of the Inverse Quantizer for each Token to which it responds. In all cases, the Tokens are also transported to the output of the



Inverse Quantizer. In most cases, the Token is unmodified by the Inverse Quantizer with the exceptions as noted below. All unrecognized Tokens are passed unmodified to the output of the Inverse Quantizer.

#### 5 B.8.7.1 SEQUENCE\_START

This Token causes the registers iq\_prediction\_mode[1:0] and iq\_mpeg\_indirection[1:0] to be reset to zero.

#### B.8.7.2 CODING\_STANDARD

10 This Token causes iq\_standard[1:0] to be loaded with the appropriate value based upon the current standard (MPEG, JPEG or H.261) being decoded.

#### B.8.7.3 PREDICTION\_MODE

15 This Token loads iq-prediction\_mode[1:0]. Although the PREDICTION\_MODE Token carries more than two bits, the Inverse Quantizer only needs access to the two lowest order bits. These determine whether or not the block is intra coded.

#### B.8.7.4 QUANT\_SCALE

This Token loads iq\_quant\_scale[4:0].

#### 20 B.8.7.5 DATA

In the present invention, this Token carries the actual quantized coefficients. The head of the token contains two bits identifying the color component and these are loaded into iq\_component[1:0]. The next sixty four Token words  
25 contain the quantized coefficients. These are modified as a result of the inverse quantization process and are replaced by the reconstructed coefficients.

If exactly sixty four extension words are not present in the Token, the behavior of the Inverse Quantizer is  
30 undefined.

The DATA Token at the input of the Inverse Quantizer carries quantized coefficients. These are represented in eleven bits in a sign-magnitude format (ten bits plus a sign bit). The value "minus zero" should not be used but  
35 is correctly interpreted as zero.

The DATA Token at the output of the Inverse Quantizer carries reconstructed coefficients. These are represented

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5 B.8.7.6 QUANT\_TABLE

The Token Head contains two bits identifying the table number that is to be used. These are placed in iq\_component[1:0]. Note that this register now contains a "table number" not a color component.

25        If the extension bit of the Token Head is zero, then the  
Inverse Quantizer will read out successive locations of the  
appropriate table starting at location zero. Each location  
becomes an extension Token word (the ninth bit will be  
zero). At the end of this operation, the Token will  
30 contain exactly sixty four extension Token words.

### B.8.7.7 JPEG TABLE SELECT

35        This token is used to load or unload translations of  
color       components       to       table       numbers       to/from

iq\_ipeg\_indirection. These translations are used in JPEG and other standards.

The Token Head contains two bits identifying the color component that is currently of interest. These are placed  
5 in iq\_component[1:0].

If the extension bit of the Token Head is one, the Token should contain one extension word, the lowest two bits of  
w h i c h   a r e   w r i t t e n   i n t o   t h e  
iq\_ipeg\_indirection[2\*iq\_component[1:0]+1:2\*iq\_component  
10 [1:0]] location. The value just read becomes a Token extension word (the upper seven bits will be zero). At the end of this operation, the Token will contain exactly one Token extension word.

| Colour component in header | bits of iq_ipeg_indirection accessed |
|----------------------------|--------------------------------------|
| 0                          | [1:0]                                |
| 1                          | [3:2]                                |
| 2                          | [5:4]                                |
| 3                          | [7:6]                                |

**Table B.8.3 JPEG\_TABLE\_SELECT action**

15 **B.8.7.8 MPEG\_TABLE\_SELECT**

This Token is used to define whether to use the default or user defined quantization tables while processing via the MPEG standard. The Token Head contains two bits. Bit zero of the header determines which bit if  
20 iq\_mpeg\_indirection is written into. Bit one is written into that location.

Since the iq\_mpeg\_indirection[1:0] register is cleared by the SEQUENCE\_START Token, it will only be necessary to use this Token if a user defined quantization table has been  
25 transmitted in the bit stream.

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### B.8.8 Microprocessor Registers

#### B.8.8.1 iq\_access

To gain microprocessor access to any of the iq registers, iq\_access must be set to one and polled until it reads back one (see B.8.6.2). Failure to do this will result in the registers being read still being controlled by the datapath and, therefore, not being stable. In the case of the igram, the accesses are locked out, reading back zeros.

Writing zero to iq\_access relinquishes control back to the datapath.

#### B.8.8.2 Iq\_coding\_standard[1:0]

This register holds the coding standard that is being implemented by the Inverse Quantizer.

| iq_coding_standard | Coding Standard |
|--------------------|-----------------|
| 0                  | H.261           |
| 1                  | JPEG            |
| 2                  | MPEG            |
| 3                  | xxx             |

Table B.8.4 Coding standard values

This register is loaded by the CODING\_STANDARD Token.

Although this is a two bit register, at present eight bits are allocated in the memory map and future implementations can deal with more than the above standards.

**B.8.8.3 Iq\_mpeg\_indirection[1:0]**

This two bit register is used during MPEG decoding operations to maintain a record of which quantization tables are to be used.

5 Iq\_mpeg\_indirection[0] controls the table that is used for intra coded blocks. If it is zero then quantization table 0 is used and is expected to contain the default quantization table. If it is one, then quantization table 2 is used and is expected to contain the user defined  
10 quantization table for intra coded blocks.

This register is loaded by the MPEG\_TABLE\_SELECT Token and is reset to zero by the SEQUENCE\_START Token.

**B.8.8.4 Iq\_ipeg\_indirection[7:0]**

15 This eight bit register determines which of the four quantization tables will be used for each of the four possible color components that occur in a JPEG scan.

- Bits [1:0] hold the table number that will be used for component zero.
- Bits [3:2] hold the table number that will be used for component one.
- Bits [5:4] hold the table number that will be used for component two.
- Bits [7:6] hold the table number that will be used for component three.

This register is affected by the JPEG\_TABLE\_SELECT Token.

**B.8.8.5 iq\_quant\_scale[4:0]**

20 This register holds the current value of the quantization scale factor. This register is loaded by the QUANT\_SCALE Token.

**B.8.8.6 iq\_component[1:0]**

25 This register usually holds a value which is translated into the Quantization Table Matrix (QTM) number. It is loaded by a number of Tokens.

The DATA Token header causes this register be loaded with the color component of the block which is about to be processed. This information is only used in JPEG and JPEG variations to determine the QTM number, which it does with  
30 reference to iq\_ipeg\_indirection[7:0]. In other standards, iq\_component[1:0] is ignored.

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The JPEG\_TABLE\_SELECT Token causes this register be loaded with a color component. It is then used as an index into iq\_ipeg\_indirection[7:0] which is accessed by the tokens body.

- 5 The QUANT\_SCALE Token causes this register to be loaded with the QTM number. This table is then either loaded from the Token (if the extended form of the Token is used) or read out from the table to form a properly extended Token.

#### B.8.8.7 iq\_prediction\_mode[1:0]

- 10 This two bit register holds the prediction mode that will be used for subsequent blocks. The only use that the Inverse Quantizer makes of this information is to decide whether or not intra coding is being used. If both bits of the register are zero, then subsequent blocks are intra  
15 coded.

This register is loaded by the PREDICTION\_MODE Token. This register is reset to zero by the SEQUENCE\_START Token.

Iq\_prediction\_mode[1:0] has no effect on the operation in JPEG and JPEG variation modes.

- 20 B.8.8.8 Iq\_ipeg\_indirection[7:0]

Iq\_ipeg\_indirection is used as a lookup table to translate color components into the QTM number. Accordingly, iq\_component is used as an index to iq\_ipeg\_indirection as shown in Table B.8.3.

- 25 This register location is written to directly by the JPEG\_TABLE\_SELECT Token if the extended form of the Token is used.

- 30 This register location is read directly by the JPEG\_TABLE\_SELECT Token if the non-extended form of the Token is used.

#### B.8.8.9 Iq\_quant\_table[3:0][63:0][7:0]

There are four quantization tables, each with 64 locations. Each location is an eight bit value. The value zero should not be used in any location.

- 35 These registers are implemented as a RAM described in B.8.6.3, "Igram".

These tables may be loaded using the QUANT\_TABLE

Token.

Note that data in these tables are stored in zig-zag scan order. Many documents represent quantization table values as a square eight by eight array of numbers. Usually, the DC term is at the top left with increasing horizontal frequency running left to right and increasing vertical frequency running top to bottom. Such tables must be read along the zig-zag scan path as the numbers are placed into the quantization table with consecutive "i".

#### 10 B.8.9 Microprocessor Register Map

| Register                 | Location | Direction | Reset State |
|--------------------------|----------|-----------|-------------|
| iq_access                | 0x30     | R/W       | 0           |
| iq_coding_standard[1:0]  | 0x31     | R/W       | 0           |
| iq_quant_scale[4:0]      | 0x32     | R/W       | ?           |
| iq_component[1:0]        | 0x33     | R/W       | ?           |
| iq_prediction_mode[1:0]  | 0x34     | R/W       | 0           |
| iq_peg_indirection[7:0]  | 0x35     | R/W       | ?           |
| iq_mpeg_indirection[1:0] | 0x36     | R/W       | 0           |
| iq_qtm_keyhole_addr[7:0] | 0x38     | R/W       | 0           |
| iq_qtm_keyhole[7:0]      | 0x39     | R/W       | ?           |

Table B.8.5 Memory Map

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**B.8.10 Test**

Test coverage to the Inverse Quantizer at the input is through the Inverse Modeler's output snoop, and at the output through the Inverse Quantizer's own snoop. Logic is covered by the Inverse Quantizer's own scan chain.

Access can be gained to `igram` without reference to `iq_access` if the `ramtest` signal is asserted.

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## SECTION B.9 IDCT

### B.9.1 Introduction

The purpose of this description of the Inverse Discrete Cosine Transform (IDCT) block is to provide a source of engineering information for the IDCT. It includes information on the following.

- purpose and main features of the IDCT
- how it was designed and verified
- structure

It is intended that the description should provide one of ordinary skill in the art sufficient information to facilitate or aid the following tasks.

- appreciation of the IDCT as a "silicon macro function"
- integration the IDCT onto another device
- development of test programs for the IDCT silicon
- modification, re-design or maintenance of the IDCT
- development of a forward DCT block

### B.9.2 Overview

A Discrete Cosine Transform/Zig-Zag (DCT/ZZ) performs a transformation on blocks of pixels wherein each block represents an area of the screen 8 pixels high by 8 pixels wide. The purpose of the transform is to represent the pixel block in a frequency domain, sorted according to frequency. Since the eye is sensitive to DC components in a picture, but much less sensitive to high frequency components, the frequency data allows each component to be reduced in magnitude separately, according to the eye's sensitivity. The process of magnitude reduction is known as quantization. The quantization process reduces the information contained in the picture, that is, the quantization process is lossy. Lossy processes give overall data compression by eliminating some information. The frequency data is sorted so that high frequencies, most likely to be quantized to zero, all appear consecutively. The consecutive zeros means that coding the quantized data by using run-length coding schemes yields further data

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compression, although run-length coding is generally not a lossy process.

The IDCT block (which actually includes an Inverse Zig-Zag RAM, or IZZ, and an IDCT) takes frequency data, which is sorted, and transforms it into spatial data. This inverse sorting process is the function of IZZ.

The picture decompression system, of which the IDCT block forms a part, specifies the pixels as integers. This means that the IDCT block must take, and yield, integer values. However, since the IDCT function is not integer based, the internal number representation uses fractional parts to maintain internal accuracy. Full floating-point arithmetic is preferable, but the implementation described herein uses fixed-point arithmetic. There is some loss of accuracy using fixed-point arithmetic, but the accuracy of this implementation exceeds the accuracy specified by H.261 and the IEEE.

#### B.9.3 Design Objectives

The main design objective, in accordance with the present invention, was to design a functionally correct IDCT block which uses a minimum silicon area. The design was also required to run with a clock speed of 30MHz under the specified operating conditions, but it was considered that the design should also be adaptable for the future. Higher clock rates will be needed in the future, and the architecture of the design allows for this wherever possible.

#### B.9.4 IDCT Interfaces Description

The IDCT block has the following interfaces.

- a 12-bit wide Token data input port
- a 9-bit wide Token data output port
- a microprocessor interface port
- a system services input port
- a test interface
- resynchronizing signals

Both the Token data ports are the standard Two-Wire Interface type previously described. The widths

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illustrated, refer to the number of bits in the data representation, not the total number of wires in a port. In addition, associated with the input Token data port are the clock and reset signals used for resynchronization to the output of the previous block. There are also two resynchronizing clocks associated with the output Token data port and used by the subsequent block.

The microprocessor interface is standard and uses four bits of address. There are also three externally decoded select inputs which are used to select the address spaces for events, internal registers and test registers. This mechanism provides the flexibility to map the IDCT address space into different positions in different chips. There is also a single event output, *idctevent*, and two i/o signals, *n\_derrd* and *n\_serrd*, which are the event tristate data wires to be connected externally to the IDCT and to the appropriate bits of the microprocessor *notdata* bus.

The system services port consists of the standard clock and reset input signals, as well as, the 2-phase override clocks and associated clock override mode select input.

The test interface consists of the JTAG clock and reset signals, the scan-path data and control signals and the *ramtest* and *chiptest* inputs.

In normal operation, the microprocessor port is inactive since the IDCT does not require any microprocessor access to achieve its specified function. Similarly, the test interface is only active when testing or verification is required.

#### **B.9.5 The Mathematical Basis for the Discrete Cosine Transformation**

In video bandwidth compression, the input data represents a square area of the picture. The transform applied must, therefore, be two-dimensional. Two-dimensional transforms are difficult to compute efficiently, but the two-dimensional DCT has the property of being separable. Separable transforms can be computed along each dimension independent of the other dimensions. This implementation

uses a one-dimensional IDCT algorithm designed specifically for mapping onto hardware; the algorithm is not appropriate for software models. The one-dimensional algorithm is applied successively to obtain a two-dimensional result.

5 The mathematical definition of the two-dimensional DCT for an N by N block of pixels is as follows:

EQ 10. forward DCT

$$Y(j, k) = \frac{2}{N} c(j) c(k) \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} X(m, n) \cos \left[ \frac{(2m+1)j\pi}{2N} \right] \cos \left[ \frac{(2n+1)k\pi}{2N} \right]$$

EQ 11. inverse DCT

$$X(m, n) = \frac{2}{N} \sum_{j=0}^{N-1} \sum_{k=0}^{N-1} c(j) c(k) Y(j, k) \cos \left[ \frac{(2m+1)j\pi}{2N} \right] \cos \left[ \frac{(2n+1)k\pi}{2N} \right]$$

Where

$$j, k = 0, 1, \dots, N-1$$

$$c(j) c(k) = \begin{cases} \frac{1}{\sqrt{2}} & j, k = 0 \\ 1 & \text{otherwise} \end{cases}$$

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$$Y = [X \ C]^T C$$

Where C is the matrix of cosine terms.

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### B.9.6 The IDCT Transform Algorithm

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dimensional answer will be scaled by 2. This can then be easily corrected in the final saturation and rounding stage by shifting.

The algorithm shown was coded in double precision floating-point C and the results of this compared with a reference IDCT (using straightforward matrix multiplication). A further stage was then used to code a bit-accurate integer version of the algorithm in C (no timing information was included) which could be used to verify the performance and accuracy of the algorithm as it would be implemented on silicon. The allowable inaccuracies of the transform are specified in the H.261 standard and this method was used to exercise the bit-accurate model and measure the delivered accuracy.

Figure 137 shows the overall IDCT Architecture in a way that illustrates the commonality between the upper and lower sections and which also shows the points at which intermediate results need to be stored. The circuit is time multiplexed to allow the upper and lower sections to be calculated separately.

#### **B.9.7 The IDCT Transform Architecture**

As described previously, the IDCT algorithm is optimized for an efficient architecture. The key features of the resulting architecture are as follows:

- significant re-use of the costly arithmetic operations
- small number of multipliers, all being constant coefficient rather than general purpose (reduces multiplier size and removes need for separate coefficient store)
- small number of latches, no more than required for pipelining the architecture
- operations are arranged so that only a single resolving operation is required per pipeline stage
- can arrange to generate results in natural order
- no complex crossbar switching or significant multiplexing (both costly in a final implementation)

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- advantage is taken of resolved results in order to remove two carry-save operations (one addition, one subtraction)

- architecture allows each stage to take 4 clock cycles, i.e., removes the requirement for very fast (large) arithmetic operations

- architecture will support much faster operation than current 30MHz pixel-clock operation by simply changing resolving operations from small/slow ripple carry to larger/faster carry-lookahead versions. The resolving operations require the largest proportion of the time required in each stage so speeding up only these operations has a significant effect on the overall operations speed, whilst having only a relatively small increase on the overall size of the transform. Further increases in speed can also be achieved by increasing the depth of pipelining.

- control of the transform data-flow is very straightforward and efficient

The diagram of the 1D Transform Micro-Architecture (Figure 141) illustrates how the algorithm is mapped onto a small set of hardware resources and then pipelined to allow the necessary performance constraints to be met. The control of this architecture is achieved by matching a "control shift-register" to the data-flow pipeline. This control is straightforward to design and is efficient in silicon layout.

The named control signals on Figure 141 (latch, sel\_byp etc.) are the various enable signals used to control the latches and, thus, the signal flow. The clock signals to the latches are not shown.

Several implementation details are significant in terms of allowing the transform architecture to meet the required accuracy standards whilst minimizing the transform size.

The techniques used generally fall into two major classes.

- Retention of maximum dynamic range, with a fixed word width, at each intermediate state by individual

control of the fixed-point position.

- Making use of statistical definition of the accuracy requirement in order to achieve accuracy by selective manipulation of arithmetic operations (rather than
- 5 increasing accuracy by simply increasing the word width of the entire transform)

- The straightforward way to design a transform would involve a simple fixed-point implementation with a fixed word-width made large enough to achieve accuracy.
- 10 Unfortunately, this approach results in much larger word widths and, therefore, a larger transform. The approach used in the present invention allows the fixed point position to vary throughout the transform in a manner that makes the maximum use of the available dynamic range for
  - 15 any particular intermediate value, achieving the maximum possible accuracy.

- Because the allowable results are specified statistically, selective adjustments can be made to any intermediate value truncation operation in order to improve
- 20 overall accuracy. The adjustments chosen are simple manipulations of LSB calculations, which have little or no cost. The alternative to this technique is to increase the word width, involving significant cost. The adjustments effectively "weight" final results in a given direction, if
  - 25 it is found that previously, these results tend in the opposite direction. By adjusting the fractional parts of results, we are effectively shifting the overall average of these results.

#### **B.9.8 IDCT Block Diagram Description**

- 30 The block diagram of the IDCT shows all the blocks that are relevant to the processing of the Token Stream. This diagram, Figure 138, does not show details of clocking, test and microprocessor access and the event mechanism. Snooper blocks, used to provide test access, are not shown
- 35 in the diagram.

##### **B.9.8.1 DATA Error Checker**

The first block is the DATA error checker and corrector,

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called "decheck" which takes and produces a 12-bit wide Token Stream, parses this stream and checks the DATA Tokens. All other Tokens are ignored and are passed straight through. The checks that are performed are for DATA Tokens with a number of extensions not equal to 64. The possible errors are termed "deficient" (<64 extensions) an `idct_too_few_event`, and "supernumerary" (>64 extensions), an `idct_too_many_event`. Such errors are signalled with the standard event mechanism, but the block also attempts simple error recovery by manipulation of the Token Stream. In the case of deficient errors, the DATA Token is packed with "0" value extensions (stops accepting input and performs insert) to make up the correct 64 extensions. In the case of a supernumerary error, the extension bit is forced to "0" for the 64th extension and all extra extensions are removed from the Token Stream.

#### B.9.8.2 Inverse Zig-Zag

The next block on the Spatial Decoder in Fig. 138 is the inverse zig-zag RAM 441, "izz", and again it takes and produces a 12-bit wide Token Stream. As with all other blocks, the stream is parsed, but only DATA Tokens are recognized. All other Tokens are passed through unchanged. DATA Tokens are also passed through, but the order of the extensions is changed. This block relies on correct DATA Tokens (i.e., 64 extensions only). If this is not true, then operation is unspecified. The reordering is done according to the standard inverse Zig-Zag pattern and, by default, is done so as to provide horizontally scanned data at the IDCT output. It is also possible to change the ordering to provide vertically scanned output. In addition to the standard IZZ ordering, this block performs an extra re-ordering of each 8-word row. This is done because of the specific requirements of the IDCT one-dimensional transform block and results in rows being output in the order (1,3,5,7,0,2,4,6) rather than (0,1,2,3,4,5,6,7).

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### B.9.8.3 Input Formatter

The next block in Figure 138 is the input formatter 442, "ip\_fmt", which formats DATA input for the first dimension of the IDCT transform. This block has a 12-bit wide Token Stream input and 22-bit wide token Stream output. DATA Tokens are shifted left so as to move the integer part to the correct significance in the IDCT transform standard 22-bit wide word, the fractional part being set to 0. This means that there are 10 bits of fraction at this point. All other Tokens are unshifted and the extra unused bits are simply set to 0.

### B.9.8.4 1-Dimensional Transform - 1st Dimension

The next block shown in Figure 138 is the first single dimension IDCT transform block 443, "oned". This inputs and outputs 22-bit wide token Streams and, as usual, the stream is parsed and DATA Tokens are recognized. All other tokens are passed through unaltered. The DATA Tokens pass through a pipelined datapath that performs an implementation of a single dimension of an 8-by-8 Inverse Discrete Cosine Transform. At the output of the first dimension, there are 7 bits of fraction in the data word. All other Tokens run through a merely shift register datapath that simply matches the DATA transform latency and are recombined into the Token Stream before output.

### B.9.8.5 Transpose RAM

The transpose RAM 444 "tram", is similar in many ways to the inverse zig-zag RAM 441 in the way it handles a Token Stream. The width of Tokens handled (22 bits) and the re-ordering performed are different, but otherwise they work in the same way and actually share much of their control logic. Again, rows are additionally re-ordered for the requirements of the following IDCT dimension as well as the fundamental swapping of columns into rows.

### B.9.8.6 1-Dimensional Transform - 2nd Dimension

The next block shown is another instance of a single dimension IDCT transform and is identical in every way to the first dimension. At the output of this dimension there

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are 4 bits of fraction.

#### **B.9.8.7 Round and Saturate**

The round-and-saturate block 446 in Figure 138, "ras", takes a 22-bit wide Token Stream containing DATA extensions in 22-bit fixed point format and outputs a 9-bit wide Token Stream where DATA extensions have been rounded (towards +ve infinity) into integers and saturated into 9-bit two's complement representation and all other Tokens have been passed straight through.

### **B.9.9 Hardware Descriptions of Blocks**

#### **B.9.9.1 Standard Block Structure**

For all the blocks that handle a Token Stream there is a standard notional structure as shown in Figure 139. This separates the two-wire interface latches from the section that performs manipulation of the Token Stream. Variations on this structure can include extra internal blocks (such as a RAM core). In some blocks shown, the structure is made less obvious in the schematic (although it does actually still exist) because of the requirement of grouping together all the "datapath" logic and separate this from all the standard cell logic. In the case of a very simple block, such as "ras", it is possible to take the latched out\_accept straight into the input two-wire latch without logical manipulation.

#### **B.9.9.2 "Decheck" - DATA Error Checking/Recovery**

The first block 440 in the Token Stream performs DATA checking and correcting as specified in the Block Diagram Overview section. The detected errors are handled with the standard event mechanism which means that events can be masked and the block can either continue with the recovery procedure when an error is detected or be stopped depending on event mask status. The IDCT should never see incorrect DATA Tokens and, therefore, the recovery that it attempted is only a fairly simple attempt to contain what may be a serious problem.

This block has a pipeline depth of two stages and is implemented entirely in zcells. The input two-wire

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interface latch is of the "front" type, meaning that all inputs arrive onto transistor gates to allow safe operation when this block (at the front of the IDCT) is on a separate power supply regime from the one preceding it. This block works by parsing a Token Stream and passing non-DATA Tokens straight through. When a DATA Token is found, a count is started of the number of extensions found after the header. If the extension bit is found to be "0" when the count does not equal 63, an error signal is generated (which goes to the event logic) and depending on the state of the mask bit for that event, "decheck" will either be stopped (i.e., no longer accept input or generate output) or will begin error recovery. The recovery mechanism for "deficient" errors uses the counter to control the insertion of the correct number of extensions into the Token Stream (the value inserted is always "0"). Obviously, input is not accepted whilst this insertion proceeds. When it is found that the extension bit is not "0" on the 64th extension, a "supernumerary" error is generated, the DATA Token is completed by forcing the extension bit to "0", and all succeeding words with the extension bit set to "1" are deleted from the Token Stream by continuing to accept data but invalidating the output.

Note that the two error signals are not persistent (unless the block is stopped) i.e., the error signal only remains active from the point when an error is detected until recovery is complete. This is a minimum of one complete cycle and can persist forever in the case of a infinitely supernumerary DATA Token.

#### 30 B.9.9.3 "Izz" and "tram" - Reordering RAMs

The "izz" 441 (inverse zig-zag RAM) and the "tram" 444 (transpose RAM) are considered here together since they both perform a variation on the same function and they have more similarities than differences. Both these blocks take a Token Stream and re-order the extensions of a DATA Token whilst passing through all other Tokens unchanged. The widths of the extensions handled and the sequences of the

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re-ordering are different, but a large section of the control logic for each RAM is identical and is actually organized into a "common control" block which is instanced in the schematic for each RAM. The difference in width has  
 5 no effect upon this control section so it is only necessary to use a different "sequence address generator" for each RAM together with RAM cores and two-wire interface blocks of the appropriate width.

The overall behavior of each RAM is essentially that of  
 10 a FIFO. This is strictly true at the Token level and a particular modification to the output order is made for the extension words of a DATA Token. The depth of the FIFO is 128 stages. This is necessary to fulfill the requirement for a sustainable 30 MHz throughout the system since output  
 15 of the FIFO is held up after the start of the output of a DATA Token is detected. This is because the features of the reordering sequences used require that a complete block of 64 extensions be gathered in the FIFO before re-ordered output can begin. More precisely, the minimum number  
 20 required is different for inverse zig-zag and transpose sequences and is somewhat less than 64 in both cases. However, the complications of controlling a FIFO which has a length which is not a power of two, means that the small saving in RAM core would be outweighed by the additional  
 25 complexity of control logic required.

The RAM core is implemented with a design which allows a read and a write (to the same or separate addresses) in a single 30 MHz cycle. This means that the RAM is effectively operating with an internal 60 MHz cycle time.

30 The re-ordering operation is performed by generating a particular sequence of read addresses ("sequence address generation") in the range 0-> 63, but not in natural order. The sequences required are specified by the standard zig-zag sequence (for eight horizontal or vertical scanning) or  
 35 by the sequence needed for normal matrix transposition. These standard sequences are then further reordered by the requirement to output each row in Odd/Even format (i.e.,

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1,3,5,7,0,2,4,6) rather than (0,1,2,3,4,5,6,7)) because of the requirements of the IDCT transform 1-dimensional blocks.

Transpose address sequence generation is quite  
 5 straightforward algorithmically. Straight transpose  
 sequence generation simply requires the generation of row  
 and column addresses separately, both implemented with  
 counters. The row re-ordering requirement simply means  
 that row addresses are generated with a simple specific  
 10 state machine rather than a natural counter.

Inverse zig-zag sequences are rather less straightforward  
 to generate algorithmically. Because of this fact, a small  
 ROM is used to hold the entire 64 6 bit values of address,  
 this being addressed with row and column counters which can  
 15 be swapped in order to change between horizontal and  
 vertical scan modes. A ROM based generator is very quick  
 to design and it further has the advantage that it is  
 trivial to implement a forward zig-zag (ROM re-program) or  
 to add other alternative sequences in the future.

#### 20 B.9.9.4 "Oned" - Single Dimension IDCT Transform

This block has a pipeline depth of 20 stages and the  
 pipeline is rigid when stalled. This rigidity greatly  
 simplifies the design and should not unduly affect overall  
 dynamics since the pipeline depth is not that great and  
 25 both dimensions come after a RAM which provides a certain  
 amount of buffering.

The block follows the standard structure, but has  
 separate paths internally for DATA Token extensions (which  
 are to be processed) and all other items which should be  
 30 passed through unchanged. Note that the schematic is drawn  
 in a particular way. First, because of the requirements to  
 group together all the datapath logic and second, to allow  
 automatic compiled code generation (this explains the  
 control logic at the top level).

35 Tokens are parsed as normal and then DATA extensions, and  
 other values, are routed respectively through two different  
 parallel paths before being re-combined with a multiplexer

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before the output two-wire interface latch block. The parallel paths are required because it is not possible to pass values unchanged through the transform datapath. The latency of the transform datapath is matched with a simple shift register to handle the remainder of the Token Stream.

The control section of "oned" needs to parse the Token Stream and control the splitting and re-combination of the Tokens. The other major section controls the transform datapath. The main mechanism for the control of this datapath is a control shift-register which matches the datapath pipeline and is tapped-off to provide the necessary control signals for each stage of the datapath pipeline.

The "oned" block has the requirement that it can only start operation on complete rows of DATA extensions, i.e., groups of 8. It is not able to handle invalid data ("Gaps") in the middle of rows, although, in fact, the operation of "izz" and the "tram" ensure that complete DATA blocks are output as an uninterrupted sequence of 64 valid extension values.

#### B.9.9.4.1 Transform Datapath

The micro-architecture of the transform datapath, "t\_dp" was previously shown in Figure 141. Note that some detail (e.g., clocking, shifts, etc.) is not shown. This diagram does illustrate, however, how the datapath operates on four values simultaneously at any stage in the pipeline. The basic sub-Structure of the datapath, i.e., the three main sections can also be seen (e.g., pre-common, common and post-common) as can the arithmetic and latch resources required. The named control signals are the enables for the pipeline latches (and the add/sub selector) which are sequenced with decodes of the control shift-register state. Note that each pipeline stage is actually four clock cycles in length.

Within the transform datapath there are a number of latch stages which are required to gather input, store intermediate results in the pipeline, and serialize the

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output. Some of latches are of the muxing type, i.e., they can be conditionally loaded from more than one source. All the latches are of the enabled type, i.e., there are separate clock and enable inputs. This means that it is  
 5 easy to generate enable signals with the correct timing, rather than having to consider issues of skew that would arise if a generated clock scheme was adopted.

The main arithmetic elements required are as follows.

- a number of fixed coefficient multipliers
- 10 (carry-save output)
- carry-save adders
- carry-save subtractors
- resolving adders
- resolving adder/subtractors

15 All arithmetic is performed in two's complement representation. This can either be in normal (resolved) form or in carry-save form (i.e., two numbers whose sum represents the actual value). All numbers are resolved before storage and only one resolving operation is  
 20 performed per pipeline stage since this is the most expensive operation in terms of time. The resolving operations performed here all use simple ripple-carry. This means that the resolvers are quite small, but relatively slow. Since the resolutions dominate the total  
 25 time in each stage, there is obviously an opportunity to speed up the entire transform by employing fast resolving arithmetic units.

#### B.9.9.5 "Ras" - Rounding and Saturation

In the present invention, the "ras" block has the task of  
 30 taking 22-bit fixed point numbers from the output of the second dimension "oned" and turning these into the correctly rounded and saturated 9-bit signed integer results required. This block also performs the necessary divide-by-4 inherent in the scheme (the  $2/N$  term) and to  
 35 further divide-by-2 required to compensate for the  $\sqrt{2}$  pre-scaling performed in each of the two dimensions. This division by 8 implies that the fixed point position is

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interpreted as being three bits further left than anticipated, i.e., treat the result as having 15 bits of integer representation and 7 bits of fraction (rather than 4 bits of fraction). The rounding mode implemented is

5 "round to positive infinity", i.e., add one for fractions of exactly 0.5. This is primarily done because it is the simplest rounding mode to implement. After rounding (a conditional increment of the integer part) is complete, this result is inspected to see whether the 9-bit signed

10 result requires saturation to the maximum or minimum value in this range. This is done by inspection of the increment carry out together with the upper bits of the original integer value.

As usual, the Token Stream is parsed and the round and

15 saturation operation is only applied to DATA Token extension values. The block has a pipeline depth of two stages and is implemented entirely in zcells.

#### **B.9.9.6 "Idctsels" - IDCT Register Select Decoder**

This block is a simple decoder which decodes the 4

20 microprocessor interface address lines, and the "sel\_test" input, into select lines for individual blocks test access (snoopers and RAMs). The block consists only of zcells combinatorial logic. The selects decoded are shown in Table B.9.2.

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| Addr.<br>(hex) | Bit<br>num | Register Name                  |
|----------------|------------|--------------------------------|
| 0x0            | 7..1       | not used                       |
|                | 0          | TRAM keyhole address           |
| 0x1            | 7..0       |                                |
| 0x2            | 7..0       | TRAM keyhole data              |
| 0x3            | 7..0       | TRAM keyhole data <sup>a</sup> |
| 0x4            | 7..0       | IZZ keyhole address            |
| 0x5            | 7..0       | IZZ keyhole data               |
| 0x6            | 7..3       | not used                       |
|                | 2          | ipfsnoop test select           |
|                | 1          | ipfsnoop valid                 |
|                | 0          | ipfsnoop accept                |
| 0x7            | 7..6       | not used                       |
|                | 5..0       | ipfsnoop bits[21:16]           |
| 0x8            | 7..0       | ipfsnoop bits[15:8]            |
| 0x9            | 7..0       | ipfsnoop bits[7:0]             |
| 0xA            | 7..3       | not used                       |
|                | 2          | d2snoop test select            |
|                | 1          | d2snoop valid                  |
|                | 0          | d2snoop accept                 |
| 0xB            | 7..6       | not used                       |
|                | 5..0       | d2snoop bits[21:16]            |
| 0xC            | 7..0       | d2snoop bits[15:8]             |
| 0xD            | 7..0       | d2snoop bits[7:0]              |
| 0xE            | 7          | outsnoop test select           |
|                | 6          | outsnoop valid                 |
|                | 5          | outsnoop accept                |
|                | 4..2       | not used                       |
| 0xF            | 1..0       | outsnoop data[9:8]             |
| 0xF            | 7..0       | outsnoop data[7:0]             |

Table B.9.1 IDCT Test Address Space

a. Repeated address



block at the front of the IDCT if incorrect DATA Tokens are detected. The single control bit is "vscan" which is set if it is required to operate the IDCT with the output vertically scanned. This bit, therefore, controls the

5 "izz" block. All the event logic and the memory mapped control bit are located in the block "idctregs".

From the point of view of the IDCT, these registers are located in the following locations. The tristate i/o wires n\_derrd and n\_serrd are used to read and write to these

10 locations as appropriate.

| Addr.<br>(hex) | Bit<br>num. | Register Name |
|----------------|-------------|---------------|
| 0x0            | 7..1        | not used      |
|                | 0           | vscan         |

Table B.9.2 IDCT Control Register Address Space

| Addr.<br>(hex) | Bit<br>name | Register Name       |
|----------------|-------------|---------------------|
| 0x0            | n_derrd     | idct_too_few_event  |
|                | n_serrd     | idct_too_many_event |
| 0x1            | n_derrd     | idct_too_few_mask   |
|                | n_serrd     | idct_too_many_mask  |

Table B.9.3 IDCT Event Address Space

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

#### B.9.11.1 Logic Design Approach

#### B.9.11.1 Logic Design Approach

In the design of all the IDCT blocks, in accordance with the invention, there was an attempt to use a unified and simple logic design strategy which would mean that it was possible to do a "safe" design in a quick and straightforward manner. For the majority of control logic, a simple scheme of using master-slaves only was adopted. Asynchronous set/reset inputs were only connected to the correct system resets. Although it might often be possible to come up with clever non-standard circuit configurations to perform the same functions more efficiently, this scheme possesses the following advantages.

- conceptually simple
- 15 · easy to design
- speed of operation is fairly obvious (cf. latch->logic->latch>logic style design) and amenable to automatic analysis
- glitches not a problem (cf. SR latches)
- 20 · using only system reset for initialization allows scan paths to work correctly
- allows automatic compiled C-code generation

There are a number of places where transparent d-type latches were used and these are listed below.

25 B.9.11.1.1 two-wire interface latches

The standard block structure uses latches for the input and output two-wire interfaces. No logic exists between an output two-wire latch and the following input two-wire latch.

30 B.9.11.1.2 ROM interface

Because of the timing requirements of the ROM circuit, latches are used in the IZZ sequence generator at the output of the ROM.

#### B.9.11.1.3 Transform Datapath and Control Shift-Register

35       It is possible to implement every pipeline storage stage  
as a full master-slave device, but because of the amount of  
storage required there is a significant savings to be had

by using latches. However, this scheme requires the user to consider several factors.

- control shift-register must now produce control signals of both phases for use as enables (i.e., need to use latches in this shift-register)
- timing analysis complicated by use of latches
- the "t\_postc" will no longer automatically produce compiled code since one latch outputs to another latch of the same phase (because of the timing of the enables this is not a problem for the circuit)

Nonetheless, the area saved by the use of latches makes it worthwhile to accept these factors in the present invention.

#### B.9.11.1.4 Microprocessor interfaces

- Due to the nature of this interface, there is a requirement for latches (and resynchronizers) in the Event and register block "idctregs" and in the keyhole logic for RAM cores.

#### B.9.11.1.5 JTAG Test Control

- These standard blocks make use of latches.

#### B.9.11.2 Circuit Design Issues

- Apart from the work done in the design of the library cells that were used in the IDCT design (standard cells, datapath library, RAMs, ROMs, etc.) there is no requirement for any transistor level circuit design in the IDCT. Circuit simulations (using Hspice) were performed of some of the known critical paths in the transform datapath and Hspice was also used to verify the results of the Critical Path Analysis (CPA) tool in the case of paths that were close to the allowed maximum length.

- Note that the IDCT is fully static in normal operation (i.e., we can stop the system clocks indefinitely) but there are dynamic nodes in scanable latches which will decay when test clocks are stopped (or very slow). Due to the non-restored nature of some nodes which exhibit a  $V_t$  drop (e.g., mux outputs) the IDCT will not be "micro-power" when static.

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### B.9.11.3 Layout Approach

The overall approach to the layout implementation of the present invention was to use BPR (some manual intervention) to lay out a complete IDCT which consisted of many zcells and a small number of macro blocks. These macro blocks were either hand-edited layout (e.g., RAMs, ROM, clock generators, datapaths) or, in the case of the "oned" block, had been built using BPR from further zcells and datapaths.

### B.9.12 Verification

final layout checks.

The design progressed in many cases by writing an M behavioral description of sub-blocks (for example, the control of datapaths and RAMs). Such descriptions were simulated in Lsim before moving onto the design of the schematic description of that block. In some cases (e.g., RAMs, clock generators) the behavioral descriptions were still used for top-level simulations.

30 Lsim switch-level simulations (with RC\_Timing mode being used) were done as a partial verification of timing performance, but also provide checks for some other potential transistor level problems (e.g., glitch sensitive circuits).



paths (some were already known) and Hspice was used to verify the CPA analysis in some critical cases.

Most Lsim simulations were performed with the standard source->block->sink methodology since the bulk of the IDCT behavior is exercised by the flow of Tokens through the device. Additional simulations are also necessary to test the features accessed through the microprocessor interface (configuration, event and test logic) and those test features accessed via JTAG/scan.

Compiled-code simulations can be readily accomplished by one of ordinary skill in the art for entire IDCT, again using the standard source->bloc->sink method and many of the same Token Streams that were used in the Lsim verification.

#### **B.9.13 Testing and Test Support**

This section deals with the mechanisms which are provided for testing and an analysis of how each of the blocks might be tested.

The three mechanisms provided for test access are as follows:

- microprocessor access to RAM cores
- microprocessor access to snoop blocks
- scan path access to control and datapath logic

There are two "snooper" blocks and one "super snooper" block in the IDCT. Figure 140 shows the positions of the snooper blocks and the other microprocessor test access.

Using these, and the two RAM blocks, it is possible to isolate each of the major blocks for the purpose of testing their behavior in relation to the Token flow. Using microprocessor access, it is possible to control the Token inputs to any block and then to observe the Token port output of that block in isolation. Furthermore, there are two separate scan paths which run through (almost) all of the flip-flops and latches in the control sections of each block and also some of the datapath latches in the case of the "oned" transform datapath pipeline. The two scan paths are denoted "a" and "b", the former running from the

"decheck" block to the "ip\_fmt" block and the latter from the first "oned" block to the "ras" block.

Access to snoopers is possible by accessing the appropriate memory mapped locations in the normal manner.

- 5 The same is true of the RAM cores (using the "ramtest" input as appropriate). The scan paths are accessed through the JTAG port in the normal way.

Each of the blocks is now discussed with reference to the various test issues.

#### 10 B.9.13.1 "Decheck"

- This block has the standard structure (see Figure 139) where two latches for the input and output two-wire interfaces surround a processing block. As usual, no scan is provided to the two-wire latches since these simply pass on data whenever enabled and have no depth of logic to be tested. In this block, the "control" section consists of a 1-stage pipeline of zcells which are all on scanpath "a". The logic in the control section is relatively simple, the most complex path is probably in the generation of the DATA extension count where a 6-bit incrementer is used.
- 15  
20

#### B.9.13.2 "Ixx"

- This block is a variant of the standard structure and includes a RAM core block added to the two-wire interface latches and the control section. The control section is implemented with zcells and a small ROM used for address sequence generation. All the zcells are on scanpath "a" and there is access to the ROM address and data via zcell latches. There is also further logic, e.g., for the generation of numbers plus the ability to increment or decrement. In addition, there is a 7-bit full adder used for read address generation. The RAM core is accessible through keyhole registers, via the microprocessor interface, see Table B.9.1.
- 25  
30

#### B.9.13.3 "lp\_fmt"

- 35 This block again has the standard structure. Control logic is implemented with some rather simple zcell logic (all on scanpath "a") but the latching and shifting/muxing

of the data is performed in a datapath with no direct access since the logic here is very shallow and simple.

#### B.9.13.4 "Oned"

Again, this block follows the standard structure and  
 5 divides into random logic and datapath sections. The zcell  
 logic is relatively straightforward; all the zcells are on  
 scanpath "a". The control signals for the transform  
 pipeline datapath are derived from a long shift register  
 consisting of zcell latches which are on the scanpath.  
 10 Additionally, some of the pipeline latches are on the  
 scanpath, this being done because there is a considerable  
 depth of logic between some stages of the pipeline (e.g.,  
 multipliers and adders). The non-DATA Tokens are passed  
 along a shift register, implemented as a datapath, and  
 15 there is no test access to any of the stages.

#### B.9.13.5 Tram'

This block is very similar to the "izz" block. In this  
 case, however, there is no ROM used in the address sequence  
 address generation. This is performed algorithmically.  
 20 All the zcell control states are on datapath "b".

#### B.9.13.6 Rras'

This block follows the standard structure and is entirely  
 implemented with zcells. The most complex logical function  
 is the 8-bit incrementer used when rounding up. All other  
 25. logic is fairly simple. All states are scanpath "b".

#### B.9.13.7 Other top-level blocks

There are several other blocks that appear at the top  
 level of the IDCT. The snoopers are obviously part of the  
 test access logic, as are the JTAG control blocks. There  
 30 are also the two clock generators which do not have any  
 special test access (although they support various test  
 features). The block "idctseis" is combinatorial zcell  
 logic for decoding microprocessor addresses and the block  
 "idctregs" contains the microprocessor accessible event and  
 35 control bits associated with the IDCT.

## SECTION B.10 Introduction

### B.10.1 Overview of the Temporal Decoder

The internal structure of the Temporal Decoder, in accordance with the invention, is shown in Figure 142.

5 All data flow between the blocks of the chip (and much of the data flow within blocks) is controlled by means of the usual two-wire interfaces and each of the arrows in Figure 142 represents a two-wire interface. The incoming token stream passes through the input interface 450 which  
10 synchronizes the data from the external system clock to the internal clock derived from the phase-locked-loop (ph0/ph1). The token stream is then split into two paths via a Top Fork 451; one stream passes to the Address Generator 452 and the other to a 256 word FIFO 453. The  
15 FIFO buffers data while data from previous I or P frames is fetched from the DRAM and processed in the Prediction Filters 454 before being added to the incoming error data from the Spatial Decoder in the Prediction Adder 455 (P and B frames). During MPEG decoding, frame reordering data  
20 must also be fetched for I and P frames so that the output frames are in the correct order, the reordered data being inserted into the stream in the Read Rudder block 456.

The Address Generator 452 generates separate addresses for forward and backward predictions, reorder, read and  
25 write-back, the data which is written back being split from the stream in the Write Rudder block 457. Finally, data is resynchronized to the external clock in the Output Interface Block 458.

All the major blocks in the Temporal Decoder are  
30 connected to the internal microprocessor interface (UPI) bus. This is derived from the external microprocessor interface (MPI) bus in the Microprocessor Interface block 459. This block has address decodes for the various blocks in the chip associated with it. Also associated with the  
35 microprocessor interface is the event logic.

The rest of the logic of the Temporal Decoder is

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concerned primarily with test. First, the IEE 1149.1 (JTAG) interface 460 provides an interface to internal scan paths as well as to JTAG boundary-scan features. Secondly, two-wire interface stages which allow intrusive access to the data flow via the microprocessor interface while in test mode are included at strategic points in the pipeline architecture.

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## SECTION B.11 Clocking, Test and Related Issues

### B.11.1 Clock Regimes

Before considering the individual functional blocks within the chip, it is helpful to have an appreciation of the clock regimes within the chip and the relationship between them.

During normal operation, most blocks of the chip run synchronously to the signal pllsysclk from the phase-locked-loop (PLL) block. The exception to this is the DRAM interface whose timing is governed by the need to be synchronous to the iftime sub-block, which generates the DRAM control signals (notwe, notoe, notcas, notras). The core of this block is clocked by the two-phase non-overlapping clocks clk0 and clk1, which are derived from the quadrature two-phase clocks supplied independently from the PLL cki0, cki1 and clkq0, clkq1.

Because the clk0, clk1 DRAM interface clocks are asynchronous to the clocks in the rest of the chip, measures have been taken to eliminate the possibility of metastable behavior (as far as practically possible) at the interfaces between the DRAM interface and the rest of the chip. The synchronization occurs in two areas: in the output interfaces of the Address Generator (addrgen/predread/psgsync, addrgen/ip\_wrt2/sync18 and addrgervip\_rd2/sync18) and in the blocks which control the "swinging" of the swing-buffer RAMs in the DRAM Interface (see section on the DRAM Interface). In each case, the synchronization process is achieved by means of three metastable-hard flip-flops in series. It should be noted that this means that clk0/clk1 are used in the output stages of the Address Generator.

In addition to these completely asynchronous clock regimes, there are a number of separate clock generators which generate two-phase non-overlapping clocks (ph0, ph1) from pllsysclk. The Address Generator, Prediction Filters and DRAM Interface each have their own clock generators; the remainder of the chip is run off a common clock

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generator. The reasons for this are twofold. First, it reduces the capacitive load on individual clock generators, allowing smaller clock drivers and reduced clock routing widths. Second, each scan path is controlled by a clock generator, so increasing the number of clock generators allows shorter scan-paths to be used.

It is necessary to resynchronize signals which are driven across these clock-regime boundaries because the minor skews between the non-overlapping clocks derived from different clock generators could mean that underlap occurred at the interfaces. Circuitry built into each "Snooper" block (see Section B.11.4) ensures that this does not occur, and Snooper blocks have been placed at the boundaries between all the clock regimes, excepting at the front of the Address Generator, where the resynchronization is performed in the Token Decode block.

#### B.11.2 Control of Clocks

Each standard clock generator generates a number of different clocks which allow operation in normal mode and scan-test mode. The control of clocks in scan-test mode is described in detail elsewhere, but it is worth noting that several of the clocks generated by a clock generator (tph0, tph1, tckm, tcks) do not usually appear to be joined to any primitive symbols on the schematics. This is because scan paths are generated automatically by a post-processor which correctly connects these clocks. From a functional point of view, the fact that the post-processor has connected different clocks from those shown on the schematics can be ignored; the behavior is the same.

During normal operation, the master clocks can be derived in a number of different ways. Table B.11.1 indicates how various modes can be selected depending on the states of the pins pllselect and override.

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| pllselect | override | Mode                                                                                                                                                                                     |
|-----------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0         | 0        | pllsysclk is connected directly to external sysclk, bypassing the PLL; DRAM Interface clocks (cki0, cki1, ckq0, ckq1) are controlled directly from the pins ti and tq.                   |
| 0         | 1        | Override mode - ph0 and ph1 clocks are controlled directly from pins tpoish and tph1ish; DRAM interface clocks (cki0, cki1, ckq0, ckq1) are controlled directly from the pins ti and tq. |
| 1         | 0        | Normal operation. pllsysclk is the clock generated by the PLL; DRAM Interface clocks are generated by the PLL.                                                                           |
| 1         | 1        | External resistors connected to ti and tq are used instead of the internal resistors (debug only).                                                                                       |

Table B.11.1 Clock Control Modes

**B.11.3 The Two-wire Interface**

The overall functionality of the two-wire interface is described in detail in the Technical Reference. However,

5 the two-wire interface is used for all block-to-block communication within the Temporal Decoder and most blocks consist of a number of pipeline stages, all of which are themselves two-wire interface stages. It is, therefore, essential to understand the internal implementation of the

10 two-wire interface in order to be able to interpret many of the schematics. In general, these internal pipeline stages are structured as shown in Figure 143.



Figure 143 shows a latch-logic-latch representation as this is the configuration which is normally used. However, when a number of stages are put together, it is equally valid to think of a "stage" as being latch-latch-logic (for many engineers a more familiar model). The use of the latch-logic-latch configuration allows all inter-block communication to be latch to latch, without any intervening logic in either the sending or receiving block.

Referring again to Figure 143, a simple two-wire interface FIFO stage can be constructed by removing the logic block, connecting the data and valid signals directly between the latches and the latched in\_valid directly into the NOR gate on the input to the in\_accept latch in the same way as out\_valid and out\_accept are gated. Data and valid signals then propagate when the corresponding accept signal is high. By ORing in\_valid with out\_accept\_reg in the manner shown, data will be accepted if in\_valid is low, even if out\_accept\_reg is low. In this way gaps (data with the valid bit low) are removed from the pipeline whenever a stall (accept signal low) occurs.

With the logic block inserted, as shown in Figure 143, in\_accept and out\_valid may also be dependent on the data or the state of the block. In the configuration shown, it is standard for any state within the block to be held in master-slave devices with the master enabled by ph1 and the slave enabled by ph0.

#### **B.11.4 Snooper Blocks**

Snooper blocks enable access to the data stream at various points in the chip via the Microprocessor Interface. There are two types of snooper blocks. Ordinary Snoopers can only be accessed in test mode where the clocks can be controlled directly. "Super Snoopers" can be accessed while the clocks are running and contain circuitry which synchronizes the asynchronous data from the Microprocessor bus to the internal chip clocks. Table B.11.2 lists the locations and types of all Snoopers in the Temporal Decoder.

| Location                 | Type          |
|--------------------------|---------------|
| addrgrvvec_pipe/snoopz31 | Snooper       |
| addrgrvcnt_pipe/midsnp   | Snooper       |
| addrgrvcnt_pipe/endsnp   | Snooper       |
| addrgrvprecread/snoopz44 | Snooper       |
| addrgrvip_wrt2/superz10  | Super Snooper |
| addrgrvip_rc2/superz10   | Super Snooper |

Table B.11.2 Snoopers in Temporal Decoder.

| Location                              | Type          |
|---------------------------------------|---------------|
| dramx/dramil/ilsnoops/snoopz15 (fsnp) | Snooper       |
| dramx/dramil/ilsnoops/snoopz15 (bsnp) | Snooper       |
| dramx/dramil/ilsnoops/superz9         | Super Snooper |
| wrudder/superz9                       | Super Snooper |
| pflts/twdfit/dimbuff/snoopk13         | Snooper       |
| pflts/bwdfit.dimbuff/snoopk13         | Snooper       |
| pflts/snoopz9                         | Snooper       |

Table B.11.2 Snoopers in Temporal Decoder

Details on the use of both Snoopers are contained in the test section. Details of the operation of the JTAG interface are contained in the JTAG document.

## SECTION B.12 Functional Blocks

### B.12.1 Top Fork

The Top Fork, in accordance with the present invention, serves two different functions. First, it forks the data stream into two separate streams: one to the Address Generator and the other to the FIFO. Second, it provides the means of starting and stopping the chip so that the chip can be configured.

The fork part aspect of the component is very simple. The same data is presented to both the Address Generator and the FIFO, and has to have been accepted by both blocks before an accept is sent back to the previous stage. Thus, the valids of the two branches of the fork are dependent on the accepts from the other branch. If the chip is in a stopped state, the valids to both branches are held low.

The chip powers up in a state where `in_accept` is held low until the configure bit is set high. This ensures that no data is accepted until the user has configured the chip. If the user needs to configure the chip at any other time, he must set the configure bit and wait until the chip has finished the current stream. The stopping process is as follows:

- 1) If the configure bit has been set, do not accept any more data after a flush token has been detected by the Top Fork.
- 2) The chip will have finished processing the stream when the FLUSH Token reaches the Read Rudder. This causes the signal `seq_done` to go high.
- 3) When `seq_done` goes high, set an event bit which can be read by the Microprocessor. The event signal can be masked by the Event block.

### B.12.2 Address Generator

In the present invention, the address generator (`addrgen`) is responsible for counting the numbers of blocks within a frame, and for generating the correct sequence of addresses for DRAM data transfers. The address generator's input is

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the token stream from the token input port (via topfork), and its output to the DRAM interface consists of addresses and other information, controlled by a request/acknowledge protocol.

5     The principal sections of the address generator are:

- token decode
- block counting and generation of the DRAM block address
- conversion of motion vector data into an address offset
- 10    · request and address generator for prediction transfers
- reorder read address generator
- write address generator

#### 15    B.12.2.1 Token Decode (tokdec)

In the Token Decoder, tokens associated with coding standards, frame and block information and motion vectors are decoded. The information extracted from the stream is stored in a set of registers which may also be accessed via the upi. The detection of a DATA token header is signalled to subsequent blocks to enable block counting and address generation. Nothing happens when running JPEG.

List of tokens decoded:

- CODING\_STANDARD
- 25   · DATA
- DEFINE\_MAX\_SAMPLING
- DEFINE\_SAMPLING
- HORIZONTAL\_MBS
- MVD\_BACKWARDS
- 30   · MVD\_FORWARDS
- PICTURE\_START
- PICTURE\_TYPE
- PREDICTION\_MODE

This block also combines information from the request generators to control the toggling of the frame pointers and to stall the input stream. The stream is stalled when a new frame appears at the input (in the form of a

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group of blocks. This is eleven macroblocks wide and three deep, and a picture is always two groups wide. The token decoder extracts the CIF bit from the PICTURE\_TYPE token and passes this to the macroblock counter to instruct it to  
 5 count groups of blocks. Instances of too few or too many blocks per component will provoke similar reactions as above.

#### **B.12.2.3 Block Calculation (blkcalc)**

The Block calculation converts the macroblock and block-  
 10 within-macroblock coordinates into coordinates for the block's position in the picture, i.e., it knocks out the level of hierarchy. This, of course, has to take into account the sampling ratios of the different color components.

#### **B.12.2.4 Base block Address (bsblkadr)**

The information from the blkcalc, together with the color component offsets, is used to calculate the block address within the linear DRAM address space. Essentially, for a given color component, the linear block address is the  
 20 number of blocks down times the width of the picture plus the number of blocks long. This is added to the color component offset to form the base block address.

#### **B.12.2.5 Vector Offset (vec\_pipe)**

The motion vector information presented by the token  
 25 decoder is in the form of horizontal and vertical pixel offset coordinates. That is, for each of the forward and backward vectors there is an (x,y) which gives the displacement in half-pixels from the block being formed to the block from which it is being predicted. Note that  
 30 these coordinates may be positive or negative. They are first scaled according to the sampling of each color component, and used to form the block and new pixel offset coordinates.

In Figure 145, the shaded area represents the block that  
 35 is being formed. The dotted outline is the block from which it is being predicted. The big arrow shows the block offset - the horizontal and vertical vector to the DRAM

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block that contains the prediction block's origin - in this case (1,4). The small arrow shows the new pixel offset - the position of the prediction block origin within that DRAM block. As the DRAM block is 8x8 bytes, the pixel offset looks to be (7,2).

The multiplier array `vmarr1a` then converts the block vector offset into a linear vector offset. The pixel information is passed to the prediction request generator as an (x,y) coordinate (`pix info`).

The frame pointer, base block address and vector offset are added to form the address of the block to be fetched from the DRAM (Inblkad3). If the pixel offset is zero, only one request is generated. If there is an offset in either the x OR y dimension, then two requests are generated - the original block address and the one either immediately to the right or immediately below. With an offset in both x and y, four requests are generated.

Synchronization between the chip clock regime and the DRAM interface clock regime takes place between the first addition (Inblkad3) and the state machine that generates the appropriate requests. Thus, the state machine (psgstate) is clocked by the DRAM interface clocks, and its scanned elements form part of the DRAM interface scan chain.

#### B.12.2.7 Reorder Read Requests and Write Requests

As there is no pixel offset involved here, each address is formed by adding the base block address to the relevant frame pointer. The reorder read uses the same frame store as the prediction and data is written back to the other frame store. Each block includes a short FIFO to store addresses as the transfer of read and write data is likely to lag the prediction transfer at the corresponding address. (This is because the read/write data interacts with stream further along the chip dataflow than the prediction data). Each block also includes synchronization between the chip clock and the DRAM interface clock.

**B.12.2.8 Offsets**

The DRAM is configured as two frame stores, each of which contains up to three color components. The frame store pointers and the color component offsets within each frame must be programmed via the upi.

**B.12.2.9 Snoopers**

In the present invention, snoopers are positioned as follows:

- Between `blkcalc` and `bsblkadr` - this interface comprises the horizontal and vertical block coordinates, the appropriate color component offset and the width of the picture in blocks (for that component).

- After `bsblkadr` - the base block address.

- After `vec_pipe` - the linear block offset, the pixel offset within the block, together with information on the prediction mode, color component and H.261 operation.

- After `Inblkad3` - the physical block address, as described under "Prediction Requests".

Super snoopers are located in the reorder read and write request generators for use during testing of the external DRAM. See the DRAM Interface section for all the details.

**B.12.2.10 Scan**

The `addrgen` block has its own scan chain, the clocking of which is controlled by the block's own clock generator (`adclkgen`). Note that the request generators at the back end of the block fall within the DRAM interface clock regime.

**B.12.3 \*\*Prediction Filters**

The overall structure of the Prediction Filters, in accordance with the present invention, is shown in Figure 146. The forward and backward filters are identical and filter the MPEG forward and backward prediction blocks. Only the forward filter is used in H.261 mode (the `h261_on` input of the backward filter should be permanently low because H.261 streams do not contain backward predictions). The entire Prediction Filters block is composed of



pipelines of two-wire interface stages.

#### B.12.3.1 A Prediction Filter

Each Prediction Filter acts completely independently of the other, processing data as soon as valid data appears at its input. It can be seen from Figure 147 that a Prediction Filter consists of four separate blocks, two of which are identical. It is best if the operation of these blocks is described independently for MPEG and H.261 operation. H.261 being the more complex, is described first.

##### B.12.3.1.1 H.261 Operation

The one-dimensional filter equation used is as follows:

$$F_i = \frac{x_{i+1} + 2x_i + x_{i-1}}{4} \quad (1 \leq i \leq 6)$$

$$F_i = x_i \text{ (otherwise)}$$

This is applied to each row of the 8x8 block by the x Prediction Filter and to each column by the y Prediction Filter. The mechanism by which this is achieved is illustrated in Figure 148, which is basically a representation of the pfltidd schematic. The filter consists of three two-wire interface pipeline stages. For the first and last pixels in a row, registers A and C are reset and the data passes unaltered through registers B, D and F (the contents of B and D being added to zero). The control of Bx2mux is set so that the output of register B is shifted left by one. This shifting is in addition to the one place which it is always shifted in any event. Thus, all values are multiplied by 4 (more of this later). For all other pixels,  $x_{i+1}$  is loaded into register C,  $x_i$  into register B and  $x_{i-1}$  into register A. It can be seen from Figure 148 that the H.261 filter equation is then implemented. Because vertical filtering is performed in

horizontal groups of three (see notes on the Dimension Buffer, below) there is no need to treat the first and last pixels in a row differently. The control and the counting of the pixels within a row is performed by the control logic associated with each 1-D filter. It should be noted that the result has not been divided by 4. Division by 16 (shift right by 4) is performed at the input of the Prediction Filters Adder (Section B.12.4.2) after both horizontal and vertical filtering has been performed, so that arithmetic accuracy is not lost. Registers DA, DD and DF pass control information down the pipeline. This includes h261\_on and last\_byte.

Of the other blocks found in the Prediction Filter, the function of the Formatter is merely to ensure that data is presented to the x-filter in the correct order. It can be seen above that this merely requires a three-stage shift register, the first stage being connected to the input of register C, the second to register B and the third to register A.

Between the x and y filters, the Dimension Buffer buffers data so that groups of three vertical pixels are presented to the y-filter. These groups of three are still processed horizontally, however, so that no transposition occurs within the Prediction Filters. Referring to Figure 149, the sequence in which pixels are output from the Dimension Buffer is illustrated in Table B.12.1.

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| Clock | Input Pixel | Output Pixel | Clock | Input Pixel | Output Pixel      |
|-------|-------------|--------------|-------|-------------|-------------------|
| 1     | 0           | 55(a)        | 17    | 16          | 7                 |
| 2     | 1           | 56           | 18    | 17          | $F(0, 3, '6) (b)$ |
| 3     | 2           | 57           | 19    | 18          | $F(1, 3, '7)$     |
| 4     | 3           | 58           | 20    | 19          | $F(2, 10, '6)$    |
| 5     | 4           | 59           | 21    | 20          | $F(3, '1, '9)$    |
| 6     | 5           | 60           | 22    | 21          | $F(4, '2, '0)$    |
| 7     | 6           | 61           | 23    | 22          | $F(5, '3, '1)$    |
| 8     | 7           | 62           | 24    | 23          | $F(6, '4, '2)$    |
| 9     | 8           | 63           | 25    | 24          | $F(7, '5, '3)$    |
| 10    | 9           | 0            | 26    | 25          | $F(8, '6, '4)$    |
| 11    | 10          | 1            | 27    | 26          | $F(9, '7, '5)$    |
| 12    | 11          | 2            | 28    | 27          | $F(10, '8, '6)$   |
| 13    | 12          | 3            | 29    | 28          | $F(11, '9, '7)$   |
| 14    | 13          | 4            | 30    | 29          | $F(12, '0, '8)$   |
| 15    | 14          | 5            | 31    | 30          | $F(13, '1, '9)$   |
| 16    | 15          | 6            | 32    | 31          | $F(14, '2, '0)$   |

**Table B.12.1: H.261 Dimension Buffer Sequence**

- Least row of pixels from previous block or invalid data if there was no previous block (or if there was a long gap between blocks.)
- $F(x)$  indicates the function in H.261 filter equation.

**B.12.3.1.2 MPEG Operation**

During MPEG operation, a Prediction Filter performs a simple half pel interpolation:

$$F_i = \frac{x_i + x_{i+1}}{2} (0 \leq i \leq 8, \text{half pel})$$

$$F_i = x_i (0 \leq i \leq 7, \text{integer pel})$$

This is the default filter operation unless the h261\_on  
 5 input is low. If the signal dim into a 1-D filter is low  
 then integer pel interpolation will be performed.  
 Accordingly, if h261\_on is low and xdim and ydim are low,  
 all pixels are passed straight through without filtering.  
 It is an obvious requirement that when the dim signal into  
 10 a 1-D filter is high, the rows (or columns) will be 8  
 pixels wide (or high). This is summarized in Table B.12.2.  
 Referring to Figure 148, "1-D Prediction Filter," the

| h261_on | xdim | ydim | Function              |
|---------|------|------|-----------------------|
| 0       | 0    | 0    | $F_i = x_i$           |
| 0       | 0    | 1    | MPEG 8x9 block        |
| 0       | 1    | 0    | MPEG 9x8 block        |
| 0       | 1    | 1    | MPEG 9x9 block        |
| 1       | 0    | 0    | H.261 Low-pass Filter |
| 1       | 0    | 1    | Illegal               |
| 1       | 1    | 0    | Illegal               |
| 1       | 1    | 1    | Illegal               |

**Table B.12.2 1-D Filter Operation**

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operation of the 1-D filter is the same for MPEG inter pel as it is for the first and last pixels in a row in H.261. For MPEG half-pel operation, register A is permanently reset and the output of register C is shifted left by 1 (the output of register B is always shifted left by 1 anyway). Thus, after a couple of clocks register F contains  $(2B + 2C)$ , four times the required result, but this is taken care of at the input of the Prediction Filters Adder, where the number, having passed through both x and y filters, is shifted right by 4.

The function of the Formatter and Dimension Buffer are also simpler in MPEG. The formatter must collect two valid pixels before passing them to the x-filter for half-pel interpolation; the Dimension Buffer only needs to buffer one row. It is worth noting that after data has passed through the x-filter, there can only ever be 8 pixels in a row, because the filtering operation converts 9-pixel rows into 8-pixel rows. "Lost" pixels are replaced by gaps in the data stream. When performing half-pel interpolation, the x-filter inserts a gap at the end of each row (after every 8 pixels); the y-filter inserts 8 gaps at the end of the block. This is significant because the group of 8 or 9 gaps at the end of a block align with DATA Token headers and other tokens between DATA Tokens in the stream coming out of the FIFO. This minimizes the worst-case throughput of the chip which occurs when 9x9 blocks are being filtered.

#### **B.12.3.2 The Prediction Filters Adder.**

During MPEG operation, predictions may be formed using an earlier picture, a later picture, or the average of the two. Predictions formed from an earlier frame termed forward predictions and those formed from a later frame are called backward predictions. The function of the Prediction Filters Adder (pfadd) is to determine which filtered prediction values are being used (forward, backward or both) and either pass through the forward or backward filtered predictions or the average of the two

(rounded towards positive infinity).

The prediction mode can only change between blocks, i.e., at power-up or after the fwd\_1st\_byte and/or bwd\_1st\_byte signals are active, indicating the last byte of the current prediction block. If the current block is a forward prediction then only fwd\_1st\_byte is examined. If it is a backward prediction then only bwd\_1st\_byte is examined. If it is a bidirectional prediction, then both fwd\_1st\_byte and bwd\_1st\_byte are examined.

The signals fwd\_on and bwd\_on determine which prediction values are used. At any time, either both or neither of these signals may be active. At start-up, or if there is a gap when no valid data is present at the inputs of the block, the block enters a state when neither signal is active.

Two criteria are used to determine the prediction mode for the next block: the signals fwd\_ima\_twin and bwd\_ima\_twin, which indicate whether a forward or backward block is part of a bidirectional prediction pair, and the buses fwd\_p\_num[1:0] and bwd\_p\_num[1:0]. These buses contain numbers which increment by one for each new prediction block or pair of prediction blocks. These blocks are necessary because, for example, if there are two forward prediction blocks followed by a bidirectional prediction block, the DRAM interface can fetch the backward block of the bidirectional prediction sufficiently far ahead so that it reaches the input of the Prediction Filters Adder before the second of the forward prediction blocks. Similarly, other sequences of backward and forward predictions can get out of sequence at the input of the Prediction Filters Adder. Thus, the next prediction mode is determined as follows:

- 1) If valid forward data is present and fwd\_ima\_twin is high, then the block stalls until valid backward data arrives with bwd\_ima\_twin set and then it goes through the blocks averaging each pair of prediction values.



The prediction adder (padder) forms the predicted frame by adding the data from the prediction filters to the error data. To compensate for the delay from the input through the address generator, DRAM interface and prediction filters, the error data passes through a 256 word FIFO (sfifo) before reaching padder.

15       The prediction adder of the present invention also includes a mechanism to detect mismatches in the data arriving from the FIFO and the prediction filters. In theory, the amount of data from the filters should exactly correspond to the number of DATA Tokens from the FIFO which  
20       involve prediction. In the event of a serious malfunction, however, padder will attempt to recover.

30       There is no snooper in either the FIFO or the prediction  
adder, as the chip can be configured to pass data from the  
token input port directly to these blocks, and to pass  
their output directly to the token output port.

35 B.12.5.1 The Write Rudder (wrudder)

The Write Rudder passes all tokens coming from the Prediction Adder on to the Read Rudder. It also passes all



data blocks in I or P pictures in MPEG, and all data blocks in H.261 to the DRAM interface so that they can be written back into the external frame stores under the control of the Address Generator. All the primary functionality is contained within one two-wire interface stage, although the write-back data passes through a snooper on its way to the DRAM interface.

The Write Rudder decodes the following tokens:

| Token Name      | Function in Write Rudder                                |
|-----------------|---------------------------------------------------------|
| CODING_STANDARD | Write-back is inhibited for JPEG streams.               |
| PICTURE_TYPE    | Write-back only occurs in I and P frames, not B frames. |
| DATA            | Only the data within DATA tokens is written back.       |

### B.12.3 Tokens Decoded by the Write Rudder

After the DATA Token header has been detected, all data bytes are output to the DRAM Interface. The end of the DATA Token is detected by in\_extn going low and this causes a flush signal to be sent to the DRAM Interface swing buffer. In normal operation, this will align with the point when the swing buffer would swing anyway, but if the DATA Token does not contain 64 bytes of data this provides a recovery mechanism (although it is likely that the next few output pictures would be incorrect).

**B.12.5.2 The Read Rudder (rrudder)**

The Read Rudder of the present invention has three functions, the two major ones relating to picture sequence reordering in MPEG:

- 5           1) To insert data which has been read-back from the external frame store into the token stream at the correct places.
- 2) To reorder picture header information in I and P pictures.
- 10          3) To detect the end of a token stream by detecting the FLUSH token (see Section B.12.1, "Top Fork").

15          The structure of the Read Rudder is illustrated in Figure 150. The entire block is made from standard two-wire interface technology. Tokens in the input interface latches are decoded and these decodes determine the operation of the block:

| Token Name         | Function in Read Rudder                                                                                            |
|--------------------|--------------------------------------------------------------------------------------------------------------------|
| FLUSH              | Signals to Top Fork.                                                                                               |
| CODING_STANDARD    | Reordering is inhibited if the coding standard is not MPEG.                                                        |
| SEQUENCE_START     | The read-back data for the first picture of a reordered sequence is invalid.                                       |
| PICTURE_START      | Signals that the current output FIFO must be swapped (I or P pictures).<br>The first of the picture header tokens. |
| PICTURE_END        | All tokens above the picture layer are allowed through.                                                            |
| TEMPORAL_REFERENCE | The second of the picture header tokens.                                                                           |
| PICTURE_TYPE       | The third of the picture header tokens.                                                                            |
| DATA               | When reordering, the contents of DATA tokens are replaced with reordered data.                                     |

**Table B.12.4 Tokens decoded by the Read Rudder**

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From the power-up, tokens are accepted from FIFO 1 (called the *current output FIFO*) until a picture start code

is encountered, after which FIFO 2 becomes the current output FIFO. Referring back to Section B.12.5.2.1, it can be seen that at this stage the three picture header tokens, PICTURE\_START, TEMPORAL\_REFERENCE and PICTURE\_START are retained in FIFO 1. The current output FIFO is swapped every time a picture start code is encountered in an I or P frame. Accordingly, the three picture header tokens are stored until the next I or P frame, at which time they will become associated with the correctly reordered data. B pictures are not reordered and, hence, pass through without any tokens being discarded. All tokens in the first picture, including PICTURE END are discarded.

During I and P pictures, the data contained in DATA Tokens in the token stream is replaced by reordered data from the DRAM Interface. During the first picture, "reordered" data is still present at the reordered data input because the Address Generator still requests the DRAM Interface to fetch it. This is considered garbage and is discarded.

### B.13.1 Overview

10       The DRAM Interface typically operates from a clock which  
is asynchronous to both the address generator and to the  
clocks of the various blocks through which data is passed.

15 Data is usually transferred between the DRAM Interface and the rest of the chip in blocks of 64 bytes (the only exception being prediction data in the Temporal Decoder). Transfers take place by means of a device known as a "swing buffer". This is essentially a pair of RAMs operated in a double-buffered configuration, with the DRAM interface filling or emptying one RAM while another part of the chip empties or fills the other RAM. A separate bus which carries an address from an address generator is associated with each swing buffer.

25 Each of the chips has four swing buffers, but the  
function of these swing buffers is different in each case.  
In the Spatial Decoder, one swing buffer is used to  
transfer coded data to the DRAM, another to read coded data  
from the DRAM, the third to transfer tokenized data to the  
30 DRAM and the fourth to read tokenized data from the DRAM.  
In the Temporal Decoder, one swing buffer is used to write  
Intra or Predicted picture data to the DRAM, the second to  
read Intra or Predicted data from the DRAM and the other  
two to read Intra or Predicted data from the DRAM and the  
35 other two to read forward and backward prediction data. In  
the Video Formatter, one swing buffer is used to transfer  
data to the DRAM and the other three are used to read data

from the DRAM, one of each of Luminance (Y) and the Red and Blue color difference data (Cr and Cb respectively).

The operation of the generic features of the DRAM Interface is described in the Spatial Decoder document.

5 The following section describes the features peculiar to the Temporal Decoder.

### B.13.2 The Temporal Decoder DRAM Interface

As mentioned in section B.13.1, the Temporal Decoder has four swing buffers: two are used to read and write decoded  
10 Intra and Predicted (I and P) picture data and these operate as described above. The other two are used to fetch prediction data.

In general, prediction data will be offset from the position of the block being processed as specified by  
15 motion vectors in x and y. Thus, the block of data to be fetched will not generally correspond to the block boundaries of the data as it was encoded (and written into the DRAM). This is illustrated in Figures 151 and 25, where the shaded area represents the block that is being  
20 formed. The dotted outline shows the block from which it is being predicted. The address generator converts the address specified by the motion vectors to a block offset (a whole number of blocks), as shown by the big arrow, and a pixel offset, as shown by the little arrow.

25 In the address generator, the frame pointer, base block address and vector offset are added to form the address of the block to be fetched from the DRAM. If the pixel offset is zero, only one request is generated. If there is an offset in either the x or y dimension, then two requests  
30 are generated - the original block address and the one either immediately to the right or immediately below. With an offset in both x and y, four requests are generated. For each block which is to be fetched, the address generator calculates start and stop addresses parameters  
35 and passes these to the DRAM interface. The use of these start and stop addresses is best illustrated by an example, as outlined below.

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Consider a pixel offset of (1, 1), as illustrated by the shaded area in Fig. 152 and Fig. 26. The address generator makes four requests, labelled A through D in the figure. The problem to be solved is how to provide the required sequence of row addresses quickly. The solution is to use "start/stop" technology, and this is described below.

Consider block A in Figure 152. Reading must start at position (1, 1) and end at position (7, 7). Assume for the moment that one byte is being read at a time (i.e. an 8 bit DRAM Interface). The x value in the coordinate pair forms the three LSBs of the address, the y value the three MSBs. The x and y start values are both 1, giving the address 9. Data is read from this address and the x value is incremented. The process is repeated until the x value reaches its stop value. At this point, the y value is incremented by 1 and the x start value is reloaded, giving an address of 17. As each byte of data is read, the x value is again incremented until it reaches its stop value. The process is repeated until both x and y values have reached their stop values. Thus, the address sequence of 9, 10, 11, 12, 13, 14, 15, 17, ..., 23, 25, ..., 31, 33, ..., ..., 57, ..., 63 is generated.

In a similar manner, the start and stop coordinates for block B are: (1, 0) and (7, 0), for block C: (0,1) and (0,7), and for block D: (0, 0) and (0, 0).

The next issue is where this data should be written. Clearly, looking at block A, the data read from address 9 should be written to address 0 in the swing buffer, the data from address 10 to address 15 in the swing buffer, and so on. Similarly, the data read from address 8 in block B should be written to address 15 in the swing buffer and the data from address 16 into address 15 in the swing buffer. This function turns out to have a very simple implementation as outlined below.

Consider block A. At the start of reading, the swing buffer address register is loaded with the inverse of the stop value, the y inverse stop value forming the 3 MSBs and

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the x inverse stop value forming the 3 LSBs. In this case, while the DRAM Interface is reading address 9 in the external DRAM, the swing buffer address is zero. The swing buffer address register is then incremented as the external DRAM address register is incremented, as illustrated in Table B.13.1:

Table B.13.1 Illustration of Prediction Addressing

| Ext DRAM Address     | Swing Buff Address | Ext DRAM Ad.<br>(Binary) | Swing Buff Ad.<br>(Binary) |
|----------------------|--------------------|--------------------------|----------------------------|
| 9 = y-start, x-start | 0 = y-stop, x-stop | 001 001                  | 000 000                    |
| 10                   | 1                  | 111 110                  | 000 001                    |
| 11                   | 2                  | 001 011                  | 000 010                    |
| 15                   | 6                  | 001 111                  | 000 110                    |
| 17 = y+1, x-start    | 8 = y+1, x-stop    | 010 001                  | 001 000                    |
| 18                   | 9                  | 010 010                  | 001 001                    |

The discussion thus far has centered on an 8 bit DRAM Interface. In the case of a 16 or 32 bit interface, a few minor modifications must be made. First, the pixel offset vector must be "clipped" so that it points to a 16 or 32 bit boundary. In the example we have been using, for block A, the first DRAM read will point to address 0, and data in addresses 0 through 3 will be read. Next, the unwanted data must be discarded. This is performed by writing all the data into the swing buffer (which must now be physically bigger than was necessary in the 8 bit case) and reading with an offset. When performing MPEG half-pel interpolation, 9 bytes in x and/or y must be read from the DRAM Interface. In this case, the address generator provides the appropriate start and stop addresses and some additional logic in the DRAM Interface is used, but there



is no fundamental change in the way the DRAM Interface operates.

The final point to note about the Temporal Decoder DRAM Interface is that additional information must be provided to the prediction filters to indicate what processing is required on the data. This consists of the following:

- a "last byte" signal indicating the last byte of a transfer (of 64, 72 or 81 bytes)
- an H.261 flag
- 10 · a bidirectional prediction flag
- two bits to indicate the block's dimensions (8 or 9 bytes in x and y)
- a two bit number to indicate the order of the blocks

The last byte flag can be generated as the data is read out of the swing buffer. The other signals are derived from the address generator and are piped through the DRAM Interface so that they are associated with the correct block of data as it is read out of the swing buffer by the prediction filter block.

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

## SECTION B.14 UPI Documentation

### B.14.1 Introduction

This document is intended to give the reader an appreciation of the operation of the microprocessor interface in accordance with the present invention. The interface is basically the same on both the SPATIAL DECODER and the Temporal Decoder, the only difference being the number of address lines.

The logic described here is purely the microprocessor internal logic. The relevant schematics are:

UPI  
UPI101  
UPI102  
DINLOGIC  
15 DINCELL  
UPIN  
TDET  
NONOVRP  
WRTGEN  
20 READGEN  
VREFCKT

The circuits UPI, UPI101, UPI102 are all the same except that the UPI01 has a 7 bit address input with the 8th bit hardwired to ground, while the other two have an 8 bit address input.

#### Input/Output Signals

The signals described here are a list of all the inputs and outputs (defined with respect to the UPI) to the UPI module with a note detailing the source or destination of these signals:

NOTRSTInputGlobal chip reset, active low, from Pad  
Input Driver  
E1InputEnable signal 1, active low, from the Pad  
Input Driver (Schmitt).  
35 E2InputEnable signal 2, active low, from the Pad  
Input Driver (Schmitt).  
RNOTWInputRead not Write signal from the Pad Input

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Driver (Schmitt).

ADDRIN[7:0]InputAddress bus signals from the Pad  
Input Drivers (Schmitt).

5 NOTDIN[7:0]InputInput data bus from the Input Pad  
Drivers of the Bi-directional Microprocessor Data  
pins (TTLin).

INT\_RNOTWOutputThe Internal Read not Write signal to  
the internal circuitry being accessed by  
microprocessor interface (See memory map).

10 INT\_ADDR[7:0]OutputThe Internal Address Bus to all  
the circuits being accessed by the microprocessor  
interface (See memory map).

INTDBUS[7:0]Input/OutputThe Internal Data bus to all the  
circuits being accessed by the microprocessor interface  
15 (See the memory map) and also the microprocessor data  
output pads. The internal Data bus transfers data which is  
the inverse to that on the pins of the chip.

READ\_STROutputAn is an internal timing signal which  
indicates a read of a location in the device memory map.

20 WRITE\_STROutputAn is an internal signal which indicates  
a write of a location in the internal memory map.

TRISTATEDPADOutputAn is an internal signal which connects  
to the microprocessor data output pads which indicates that  
they should be tristate.

#### 25 General Comments:

The UPI schematic consists of 6 smaller modules:  
NONOVRLP, UPIN, DINLOGIC, VREFCKT, READGEN, WRTGEN. It  
should be noted from the overall list of signals that there  
are no clock signals associated with the microprocessor  
30 interface other than the microprocessor bus timing signals  
which are asynchronous to all the other timing signals on  
the chip. Therefore, no timing relationship should be  
assumed between the operation of the microprocessor and the  
rest of the device other than those that can be forced by  
35 external control. For example, stopping of the System  
clock externally while accessing the microprocessor  
interface on a test system.

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The other implication of not having a clock in the UPI is that some internal timing is self timed. That is, the delay of some signals is controlled internally to the UPI block.

5 The overall function of the UPI is to take the address, data and enable and read/write signals from the outside world and format them so that they can drive the internal circuits correctly. The internal signals that define access to the memory map are INT\_RNOTW\_INT\_ADDR[...],  
 10 INTDBUS[...] and READ\_STR and WRITE\_STR. The timing relationship of these signals is shown below for a read cycle and a write cycle. It should be noted that although the datasheet definition and the following diagram always shows a chip enable cycle, the circuit operation is such  
 15 that the enable can be held low and the address can be cycled to do successive read or write operations. This function is possible because of the address transition circuits.

Also, the presence of the INT\_RNOTW and the READ\_STR, WRITE\_STR does reflect some redundancy. It allows internal  
 20 circuits to use either a separate READ\_STR and WRITE\_STR (and ignore INT\_RNOTW) or to use the INT\_RNOTW and a separate Strobe signal (Strobe signal being derived from OR of READ\_STR and WRITE\_STR).

25 The internal databus is precharged High during a read cycle and it also has resistive pullups so that for extended periods when the internal data bus is not driven it will default to the 0xFF condition. As the internal databus is the inverse of the data on the pins, this  
 30 translates to 0x00 on the external pins, when they are enabled. This means that, if any external cycle accesses a register or a bit of a register which is a hole in the memory map, then the output data is indeterminate and is Low.

#### Circuit Details:

35 UPIN -

This circuit is the overall change detect block. It contains a sub-circuit called TDET which is a single bit

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change detect circuit. UPIN has a TDET module for each address bit and rnotw and for each enable signal. UPIN also contains some combinatorial logic to gate together the outputs of the change detect circuits. This gating

5 generates the signals:

TRAN- which indicates a transition on one of the input signals, and

UPD-DONE- which indicates that transitions have been completed and a cycle can be performed.

10 CHIP\_EN- which indicates that the chip has been selected.

TDET-

This is the single bit change detect circuit. It consists of a 2 latches, and 2 exclusive OR gates. The first latch is clocked by the signal SAMPLE and the second  
15 by the signal UPDATE. These two non-overlapping signals come from the module NONOVRLP. The general operation is such that an input transition causes a CHANGE which, in turn, causes a SAMPLE. All input changes while SAMPLE is high are accepted and when input changes cease then CHANGE goes low and SAMPLE goes low which causes UPDATE to go high  
20 which then transfers data to the output latch and indicates UPD\_DONE.

NONOVRLP-

This circuit is basically a non-overlapping clock  
25 generator which inputs TRAN and generates SAMPLE and UPDATE. The external gating on the output of UPDATE stops UPDATE from going high until a write pulse has been completed.

DINLOGIC-

30 This module consists of eight instances of the data input circuit DINCELL and some gating to drive the TRISTATEPAD signal. This indicates that the output data port will only drive if Enable1 is low, Enable2 is low, RnotW is high and the internal read\_str is high.

35 DINCELL-

This circuit consists of the data input latch and a tristate driver to drive the internal databus. Data from

the input pad is latched when the signal DATAHOLD is high and when both Enable1 and Enable2 are low. The tristate driver drives the internal data bus whenever the internal signal INT\_RNOTW is low. The internal databus precharge transistor and the bus pullup are also included in this module.

#### WRTGEN-

This module generates the WRITE\_STR, and the latch signal DATAHOLD for the data latches. The write strobe is a self timed signal, however, the self time delay is defined in the VREFCKT. The output from the timing circuit RESETWRITE is used to terminate the WRITE\_STR signal. It should be noted that the actual write pulse which writes a register only occurs after an access cycle is concluded. This is because the data input to the chip is sampled only on the back edge of the cycle. Hence, data is only valid after a normal access cycle has concluded.

#### READGEN-

This circuit, as its name suggests, generates the READ\_STR and it also generates the PRECH signal which is used to precharge the internal databus. The PRECH signal is also a self timed signal whose period is dependant on VREFCKT and also on the voltage on the internal databus. The READ\_STR is not self timed, but lasts from the end of the precharge period until the end of the cycle. The precharge circuitry uses inverters with their transfer characteristic biased so that they need a voltage of approximately 75% of supply before they invert. This circuit guarantees that the internal bus is correctly precharged before a READ\_STR begins. In order to stop a PRECH pulse tending to zero width if the internal bus is already precharged, the timing circuit guarantees a minimum, width via the signal RESETREAD.

#### VREFCKT-

The VREFCKT is the only circuit which controls the self timing of the interface. Both the delays, 1/Width of WRITE\_STR and 2/Width of PRECH, are controlled by a current

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## SECTION C.1 Overview

### C.1.1. Introduction

The structure of the image Formatter, in accordance with the present invention, is shown in Figure 155. There are  
5 two address generators, one for writing and one for reading, a buffer manager which supervises the two address generators and which provides frame-rate conversion, a data processing pipeline, including both vertical and horizontal unsamplers, color-space conversion and gamma correction,  
10 and a final control block which regulates the output of the processing pipeline.

### C.1.2 Buffer manager

Tokens arriving at the input to the Image Formatter are buffered in the FIFO and then transferred into the buffer  
15 manager. This block detects the arrival of new pictures and determines the availability of a buffer in which to store each picture. If there is a buffer available, it is allocated to the arriving picture and its index is transferred to the write address generator. If there is no  
20 buffer available, the incoming picture will be stalled until one becomes available. All tokens are passed on to the write address generator.

Each time the read address generator receives a VSYNC signal from the display system, a request is made to the  
25 buffer manager for a new display buffer index. If there is a buffer containing complete picture data, and that picture is deemed ready for display, then that buffer's index will be passed to the display address generator. If not, the buffer manager sends the index of the last buffer to be  
30 displayed. At start-up, zero is passed as the index until the first buffer is full.

A picture is ready for display if its number (calculated as each picture is input) is greater than or equal to the picture number which is expected at the display  
35 (presentation number) given the encoding frame rate. The expected number is determined by counting picture clock

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pulses, where picture clock can be generated either locally by the clock dividers, or externally. This technology allows frame-rate conversion (e.g., 2-3 pull-down).

External DRAM is used for the buffers, which can be either two or three in number. Three are necessary if frame-rate conversion is to be effected.

### C.1.3 Write Address Generator

The write address generator receives tokens from the buffer manager and detects the arrival of each new DATA Token. As each DATA Token arrives, the address generator calculates a new address for the DRAM interface for storing the arriving block. The raw data is then passed to the DRAM interface where it is written into a swing buffer. Note that DRAM addresses are block addresses, and pictures in the DRAM are organized as rasters of blocks. Incoming picture data, however, is actually organized sequences of macroblocks, so the address generation algorithm must take into account line-width (in blocks) offsets for the lower rows of blocks within the macroblock.

The arrival buffer index provided by the buffer manager is used as an address offset for the whole of the picture being stored. Furthermore, each component is stored in a separate area within the specified buffer, so component offsets are also used in the calculation.

### C.1.4 Read Address Generator

The Read Address Generator (dispaddr) does not receive or generate tokens, it generates addresses only. In response to a VSYNC, it may, depending on field\_info, read\_start, sync\_mode, and lsb\_invert, request a buffer index from the buffer manager. Having received an index, it generates three sets of addresses, one for each component, for the current picture to be read in raster order. Different setups allow for: interlaced/progressive display and/or data, vertical unsampling, and field synchronization (to an interlaced display). At the lower level, the Read Address Generator converts base addresses into a sequence of block addresses and byte counts for each

## 5 C.1.5 Output Pipeline

### C.1.6 Timing Regimes

Each of the two aforementioned clocks drives a number of  
25 on-chip clock generators. The FIFO, buffer manager and  
read address generator operate from the same clock (D $\Phi$ )  
with the write address generator using a similar, but  
separate clock (W $\Phi$ ). Data is clocked into the DRAM  
interface on an internal DRAM interface clock, (out $\Phi$ ). D $\Phi$ ,  
30 W $\Phi$  and out $\Phi$  are all generated from sysclk.

Data is read out of the DRAM interface on `bifR $\phi$` , and is transferred to the section of the output pipeline named "bushy\_ne" (north-east - by virtue of its physical location) which operates on clocks denoted by `NE $\phi$` . The section of the pipeline from the gamma RAMs onward is

clocked on a separate, but similar, clock ( $R\phi$ ).  $bifR\phi$ ,  $NE\phi$  and  $R\phi$  are all derived from the pixel clock,  $pixin$ .

For testing, all of the major interfaces between blocks have either snoopers or super-snoopers attached. This  
5 depends on the timing regimes and the type of access required. Block boundaries between separate, but similar timing regimes have retiming latches associated therewith.

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## SECTION C.2 Buffer Management

### C.2.1. Introduction

The purpose of the buffer management block, in accordance with the present invention, is to supply the address generators with indices identifying any of either two or three external buffers for writing and reading of picture data. The allocation of these indices is influenced by three principal factors, each representing the effect of one of the timing regimes in operation. These are the rate at which picture data arrives at the input to Image Formatter (coded data rate), the rate at which data is displayed (display data rate), and the frame rate of the encoded video sequence (presentation rate).

### C.2.2 Functional Overview

A three-buffer system allows the presentation rate and the display rate to differ (e.g., 2-3 pulldown), so that frames are either repeated or skipped as necessary to achieve the best possible sequence of frames given the timing constraints of the system. Pictures which present some difficulty in decoding may also be accommodated in a similar way, so that if a picture takes longer than the available display time to decode, the previous frame will be repeated while everything else "catches up". In a two-buffer system, the three timing regimes must be locked - it is the third buffer which provides the flexibility for taking up the slack.

The buffer manager operates by maintaining certain status information associated with each external buffer. This includes flags indicating if the buffer is in use, if it is full of data, or ready for display, and the picture number within the sequence of the picture currently stored in the buffer. The presentation number is also recorded, this being a number which increments every time a picture clock pulse is received, and represents the picture number which is currently expected for display based on the frame rate of the encoded sequence.

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### C.2.3.1.1. Interface to bm front

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field number.

#### C.2.3.1.4 Microprocessor Interface

The buffer manager block uses four bits of microprocessor address space, together with the 8-bit data bus and read and write strobes. There are two select signals, one indicating user-accessible locations and the other indicating test locations which should not require access under normal operating conditions.

#### C.2.3.1.5 Events

The buffer manager is capable of producing two different events, index found and late arrival. The first of these is asserted when a picture arrives and its PICTURE\_START extension byte (picture index) matches the value written into the BU\_BM\_TARGET\_IX register at setup. The second event occurs when a display buffer is allocated and its picture number is less than the current presentation number, i.e., the processing in the system pipeline up to the buffer manager has not managed to keep up with the presentation requirements.

#### C.2.3.1.6 Picture Clock

In the present invention, picture clock is the clock signal for the presentation number counter and is either generated on-chip or taken from an external source (normally the display system). The buffer manager accepts both of these signals and selects one based on the value of pclk\_ext (a bit in the buffer manager's control register). This signal also acts as the enable for the pad picoutpad, so that if the Image Formatter is generating its own picture clock, this signal is also available as an output from the chip.

#### C.2.3.2. Major Blocks

The following sections describe the various hardware blocks that make up the buffer manager schematic (bmlogic).

##### C.2.3.2.1 Input/Output block (bm input)

This module contains all of the hardware associated with the four two-wire interfaces of the buffer manager (input and output data, drq\_valid/accept and disp\_valid/accept).

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The display index part of this module comprises the two-wire interfaces together with equivalent "go" signals as for data. The rst\_fld bit also happens here, this being a signal which, if set, remains high until disp\_valid has been high for one cycle. Thereafter, it is reset. In addition, rst\_fld is reset after a FLUSH token has caused all of the external buffers to be flagged either as EMPTY or IN\_USE by the display buffer. This is the same point at which both picture numbers and presentation number are reset.

#### C.2.3.2.2 Index block (bm index)

30       The Index block consists mainly of the 2-bit registers  
denoting the various strategic buffer indices. These are  
arr\_buf, the buffer to which arriving picture data is being  
written, disp\_buf, the buffer from which picture data is  
being read for display, and rdy\_buf, the index of the  
35       buffer containing the most up to date picture which could  
be displayed if a buffer was requested by dispaddr. There  
is also a register containing buf\_ix, which is used as a



general pointer to a buffer. This register gets incremented ("D" input to mux) to cycle through the buffers examining their status, or which gets assigned the value of one of arr\_buf, disp\_buf or rdy\_buf when the status needs changing. All of these registers (ph0 versions) are accessible from the microprocessor as part of the test address space. Old\_ix is just a re-timed version of buf\_ix and is used for enabling buffer status and picture number registers in the bm\_stus block. Both buf\_ix and old\_ix are decoded into three signals (each can hold the value 1 to 3) which are output from this block. Other outputs indicate whether buf\_ix has the same value as either arr\_buf or disp\_buf, and whether either of rdy\_buf and disp\_buf have the value zero. Zero is not a reference to a buffer. It merely indicates that there is no arrival/display/ready buffer currently allocated.

Arr\_buf and disp\_buf are enabled by their respective two-wire interface output accept registers.

Additional circuitry at the bmlogic level is used to determine if the current buffer index (buf\_ix) is equal to the maximum index in use as defined by the value written into the control register at setup. A "1" in the control register indicates a three-buffer system, and a "0" indicates a two-buffer system.

#### 25 C.2.3.2.3 Buffer Status

The main components in the buffer status are status and picture number registers for each buffer. Each of the groups of three is a master-slave arrangement where the slaves are the banks of three registers, and the master is a single register whose output is directed to one of the slaves (switched, using register enables, by old\_ix). One of the possible inputs to the master is multiplexed between the different slave outputs (indexed by buf\_ix at the bmlogic level). Buffer status, which is decoded at the bmlogic level, for use in the state machine logic can take any of the values shown in Table C.2.1, or recirculate its previous value. Picture number can take the previous value

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or the previous value incremented by one (or one plus delta, the difference between actual and expected temporal reference, in the case of H.261). This value is supplied by the 8-bit adder present in the block. The first input  
 5 to this adder is this\_pnum, the picture number of the data currently being written.

| Buffer Status | Value |
|---------------|-------|
| EMPTY         | 00    |
| FULL          | 01    |
| READY         | 10    |
| IN_USE        | 11    |

Table C.2.1 Buffer Status Values

This needs to be stored separately (in its own master-slave arrangement) so that any of the three buffer picture number  
 10 registers can be easily updated based on the current (or previous) picture number rather than on their own previous picture number (which is almost always out of date). This\_pnum is reset to -1 so that when the first picture arrives it is added to the output from the adder and,  
 15 hence, the input to the first buffer picture number register, is zero.

Note that in the current version, delta is connected to zero because of the absence of the temporal reference block which should supply the value.

#### 20 C.2.3.2.4 Presentation Number

The 8-bit presentation number register has an associated presentation flag which is used in the state machine to indicate that the presentation number has changed since it

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was last examined. This is necessary because the picture clock is essentially asynchronous and may be active during any state, not just those which are concerned with the presentation number. The rest of the circuitry in this block is concerned with detecting that a picture clock pulse has occurred and "remembering" this fact. In this way, the presentation number can be updated at a time when it is valid to do so. A representative sequence of events is shown in Figure 156. The signal `incr_prn` goes active the cycle after the re-timed picture clock rising edge, and persists until a state is entered during which presentation number can be modified. This is indicated by the signal `en_prnum`. The reason for only allowing presentation number to be updated during certain states is because it is used to drive a significant amount of logic, including a standard-cell, not-very-fast 8-bit adder to provide the signal `rdyst`. It must, therefore, be changed only during states in which the subsequent state does not use the result.

#### 20 C.2.3.2.5 Temporal Reference

The temporal reference block in accordance with the present invention, has been omitted from the current embodiment of the Image Formatter, but its operation is described here for completeness.

25 The function of this block is to calculate delta, the difference between the temporal reference value received in a token in an H,261 data stream, and the "expected" temporal reference (one plus the previous value). This allows frames to be skipped in H.261. Temporal reference tokens are ignored in all non-H.261 streams. The calculated value is used in the status block to calculate picture numbers for the buffers. The effect of omitting the block from `bmlogic` is that picture numbers will always be sequential in any sequence, even if the H.261 stream indicates that some should be skipped.

The main components of the block (visible in the schematic `bm_tref`) are registers for `tr`, `exptr` and `delta`.

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In the invention, tr is reset to zero and loaded, when appropriate, from the input data register. Similarly, exptr is reset to -1, and is incremented by either 1 or delta during the sequence of temporal reference states. In addition, delta is reset to zero and is loaded with the difference between the other two registers. All three registers are reset after a FLUSH token. The adder in this block is used for calculation of both delta and exptr, i.e., a subtract and an add operation, respectively, and is controlled by the signal delta\_calc.

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| Signal Name | Logic Expression                                              |
|-------------|---------------------------------------------------------------|
| A           | ST_PRESENT.presflg.(bstate==FULL).rdytsl.(rdy==0) (ix==max)   |
| B           | ST_PRESENT.presflg.(bstate==FULL).rdytsl.(rdy==0) (x!=max)    |
| C           | ST_PRESENT.presflg.(bstate==FULL).rdytsl.(rdy!=0)             |
| D           | ST_PRESENT.presflg.(((bstate==FULL).rdytsl).(ix==max)         |
| E           | ST_PRESENT.presflg.(((bstate==FULL).rdytsl).(ix!=max)         |
| F           | ST_PRESENT.presflg                                            |
| G           | ST_DRQ.drq_valid.disp_acc.(rdy==0).(disp!=0)                  |
| PP          | ST_DRQ.drq_valid.disp_acc.(rdy==0).(disp!=0).fromps           |
| QQ          | ST_DRQ.drq_valid.disp_acc.(rdy==0).(disp!=0).fromfl           |
| RR          | ST_DRQ.drq_valid.disp_acc.(rdy==0).(disp!=0).!(fromps+fromfl) |
| H           | ST_DRQ.drq_valid.disp_acc.(rdy!=0).(disp!=0)                  |
| I           | ST_DRQ.drq_valid.disp_acc.(rdy!=0).(disp==0)                  |
| J           | ST_DRQ.drq_valid.disp_acc.(rdy==0).(disp==0).fromps           |
| NN          | ST_DRQ.drq_valid.disp_acc.(rdy==0).(disp==0).fromfl           |
| OO          | ST_DRQ.drq_valid.disp_acc.(rdy==0).(disp==0).!(fromps+fromfl) |
| K           | ST_DRQ.!(drq_valid.disp_acc).fromps                           |
| LL          | ST_DRQ.!(drq_valid.disp_acc).fromfl                           |
| MM          | ST_DRQ.!(drq_valid.disp_acc).!(fromps+fromfl)                 |
| L           | ST_TOKEN.ivr.oar.(idr==TEMPORAL_REFERENCE)                    |
| SS          | ST_TOKEN.ivr.oar.(idr==TEMPORAL_REFERENCE).H251               |
| TT          | ST_TOKEN.ivr.oar.(idr==TEMPORAL_REFERENCE).H251               |
| M           | ST_TOKEN.ivr.oar.(idr==FLUSH)                                 |
| N           | ST_TOKEN.ivr.oar.(idr==PICTURE_START)                         |
| O           | ST_TOKEN.ivr.oar.(idr==PICTURE_END)                           |
| P           | ST_TOKEN.ivr.oar.(idr==<OTHER_TOKEN>)                         |
| JJ          | ST_TOKEN.ivr.oar.(idr==<OTHER_TOKEN>).in_extn                 |
| KK          | ST_TOKEN.ivr.oar.(idr==<OTHER_TOKEN>).lin_extn                |
| Q           | ST_TOKEN.!(ivr.oar)                                           |

Table C.2.2 Signal Names Used in the State Machine

| Signal Name | Logic Expression                                              |
|-------------|---------------------------------------------------------------|
| S           | ST_PICTURE_END.(ix==arr).!rdyst.oar                           |
| T           | ST_PICTURE_END.(ix==arr).rdyst.(rdy==0).oar                   |
| U           | ST_PICTURE_END.(ix==arr).rdyst.(rdy!=0).oar                   |
| VV          | ST_PICTURE_END.oar                                            |
| RorVV       | ST_PICTURE_END.!(ix==arr).oar                                 |
| V           | ST_TEMP_REF0.ivr.oar                                          |
| W           | ST_TEMP_REF0.!(ivr.oar)                                       |
| X           | ST_OUTPUT_TAIL.ivr.oar                                        |
| FF          | ST_OUTPUT_TAIL.ivr.oar.in_extn                                |
| Y           | ST_OUTPUT_TAIL.!(ivr.oar)                                     |
| GG          | ST_OUTPUT_TAIL.!(ivr.oar).in_extn                             |
| DD          | ST_FLUSH.(ix==max).((bstate==VAC)+((bstate==USE).(ix==disp))) |
| Z           | ST_FLUSH.(ix!=max).((bstate==VAC)+((bstate==USE).(ix==disp))) |
| DDorEE      | !((bstate==VAC)+((bstate==USE).(ix==disp)))+(ix==max)         |
| AA          | ST_ALLOC.(bstate==VAC).oar                                    |
| BB          | ST_ALLOC.(bstate!=VAC).(ix==max)                              |
| CC          | ST_ALLOC.(bstate!=VAC).(ix!=max)                              |
| UU          | ST_ALLOC.!.oar                                                |

Table C.2.2 Signal names Used in the State Machine

#### C.2.3.2.8 Monitoring Operation (bminfo)

In the present invention, the module, bminfo, is included so that buffer status information, index values and presentation number can be observed during simulations. It is written in M and produces an output each time one of its inputs changes.

#### C.2.3.3 Register Address Map

The buffer manager's address space is split into two areas, user-accessible and test. There are, therefore, two separate enable wires derived from range decodes at the top-level. Table C.2.3 shows the user-accessible registers, and Table C.2.4 shows the contents of the test space.

| Register Name   | Address | Bits  | Reset State | Function                         |
|-----------------|---------|-------|-------------|----------------------------------|
| BU_BM_ACCESS    | 0x10    | [0]   | 1           | Access bit for buffer manager    |
| BU_BM_CTL0      | 0x11    | [0]   | 1           | Max buf isb. 1 x3 buffers 0->2   |
|                 |         | [1]   | 1           | External picture clock select    |
| BU_BM_TARGET_IX | 0x12    | [3:0] | 0x0         | For detecting arrival of picture |
| BU_BM_PRES_NUM  | 0x13    | [7:0] | 0x00        | Presentation number              |
| BU_BM_THIS_PNUM | 0x14    | [7:0] | 0xFF        | Current picture number           |
| BU_BM_PIC_NUM0  | 0x15    | [7:0] | none        | Picture number in buffer 1       |
| BU_BM_PIC_NUM1  | 0x16    | [7:0] | none        | Picture number in buffer 2       |
| BU_BM_PIC_NUM2  | 0x17    | [7:0] | none        | Picture number in buffer 3       |
| BU_BM_TEMP_REF  | 0x18    | [4:0] | 0x00        | Temporal reference from stream   |

Table C.2.3 User-Accessible Registers

| Register Name   | Address | Bits  | Reset State | Function                    |
|-----------------|---------|-------|-------------|-----------------------------|
| BU_BM_PRES_FLAG | 0x80    | [0]   | 0           | Presentation flag           |
| BU_BM_EXP_TR    | 0x81    | [4:0] | 0xFF        | Expected temporal reference |
| BU_BM_TR_DELTA  | 0x82    | [4:0] | 0x00        | Delta                       |
| BU_BM_ARR_IX    | 0x83    | [1:0] | 0x0         | Arrival buffer index        |
| BU_BM_DSP_IX    | 0x84    | [1:0] | 0x0         | Display buffer index        |
| BU_BM_RDY_IX    | 0x85    | [1:0] | 0x0         | Ready buffer index          |
| BU_BM_BSTATE3   | 0x86    | [1:0] | 0x0         | Buffer 3 status             |
| BU_BM_BSTATE2   | 0x87    | [1:0] | 0x0         | Buffer 2 status             |
| BU_BM_BSTATE1   | 0x88    | [1:0] | 0x0         | Buffer 1 status             |
| BU_BM_INDEX     | 0x89    | [1:0] | 0x0         | Current buffer index        |
| BU_BM_STATE     | 0x8A    | [4:0] | 0x00        | Buffer manager state        |
| BU_BM_FROMPS    | 0x8B    | [0]   | 0x0         | From PICTURE_START flag     |
| BU_BM_FROMFL    | 0x8C    | [0]   | 0x0         | From FLUSH_TOKEN flag       |

Table C.2.4 Test Registers

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#### C.2.4 Operation of The State Machine

There are 19 states in the buffer manager's state machine, as detailed in Table C.2.5. These interact as shown in Figure 157, and also as described in the behavioral description bmlogic.M.

| State       | Value |
|-------------|-------|
| PRES0       | 0x00  |
| PRES1       | 0x10  |
| ERROR       | 0x1F  |
| TEMP_REF0   | 0x04  |
| TEMP_REF1   | 0x05  |
| TEMP_REF2   | 0x06  |
| TEMP_REF3   | 0x07  |
| ALLOC       | 0x03  |
| NEW_EXP_TR  | 0x0D  |
| SET_ARR_IX  | 0x0E  |
| NEW_PIC_NUM | 0x0F  |
| FLUSH       | 0x01  |
| DRQ         | 0x0B  |
| TOKEN       | 0x0C  |
| OUTPUT_TAIL | 0x08  |
| VACATE_RDY  | 0x17  |
| USE_RDY     | 0x0A  |
| VACATE_DISP | 0x09  |
| PICTURE_END | 0x02  |

### Table C.2.5 Buffer States

#### C.2.4.1 The Reset State

The reset state is PRES0, with flags set to zero such that the main loop circulated initially.

#### C.2.4.2 The Main Loop

5     The main loop of the state machine comprises the states shown in Figure 153 (high-lighted in the main diagram - Figure 152). States PRES0 and PRES1 are concerned with detecting a picture clock via the signal presflg. Two cycles are allowed for the tests involved since they all  
10   depend on the value of rdyst, the adder output signal described in C.2.3.2.4. If a presentation flag is detected, all of the buffers are examined for possible 'readiness', otherwise the state machine just advances to state DRQ. Each cycle around the PRES0-PRES1 loop examines  
15   a different buffer, checking for full and ready conditions. If these are met, the previous ready buffer (if one exists) is cleared, the new ready buffer is allocated and its status is updated. This process is repeated until all buffers have been examined (index == max buf) and the state  
20   then advances. A buffer is deemed to be ready for display when any of the following is true:

```
(pic_num > pres_num) && ((pic_num - pres_num) >= 128)
or
(pic_num < pres_num) && ((pres_num - pic_num) <= 128)
or
pic_num == pres_num
```

State DRQ checks for a request for a display buffer (drq\_valid\_reg && disp\_acc\_reg). If there is no request the state advances (normally to state TOKEN - as will be  
25   described later). Otherwise, a display buffer index is issued as follows. If there is no ready buffer, the previous index is re-issued or, if there is no previous display buffer, a null index (zero) is issued. If a buffer

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The just-completed buffer is tested for readiness and given the status either FULL or READY depending on the result of the test. If it is ready, rdy\_buf is given the value of its index and the set\_la\_ev signal (late arrival event) is set high (indicating that the expected display has got ahead in time of the decoding). The new value of arr\_buf now becomes zero and, if the previous ready buffer needs its status clearing, the index is set to point there and control moves to state VACATE\_RDY. Otherwise, the index is reset to 1 and control returns to the start of the main loop.

When a PICTURE\_START token arrives during state TOKEN, the flag from\_ps is set, causing the basic state machine loop to be changed such that state ALLOC is visited instead of state TOKEN. State ALLOC is concerned with allocating an arrival buffer (into which the arriving picture data can be written), and cycles through the buffers until it finds one whose status is VACANT. A buffer will only be allocated if out\_acc\_reg is high since it is output on the data two-wire interface. Accordingly, cycling around the loop will continue until this is indeed the case. Once a suitable arrival buffer has been found, the index is allocated to arr\_buf and its status is flagged as IN\_USE. Index is set to 1, the flag from\_ps is reset, and the state is set to advance to NEW EXP TR. A check is made on the

When a PICTURE\_START token arrives during state TOKEN, the flag from\_ps is set, causing the basic state machine loop to be changed such that state ALLOC is visited instead of state TOKEN. State ALLOC is concerned with allocating an arrival buffer (into which the arriving picture data can be written), and cycles through the buffers until it finds one whose status is VACANT. A buffer will only be allocated if out\_acc\_reg is high since it is output on the data two-wire interface. Accordingly, cycling around the loop will continue until this is indeed the case. Once a suitable arrival buffer has been found, the index is allocated to arr\_buf and its status is flagged as IN\_USE. Index is set to 1, the flag from\_ps is reset, and the state is set to advance to NEW\_EXP\_TR. A check is made on the

5       The three states NEW\_EXP\_TR, SET\_ARR\_IX and NEW\_PIC\_NUM  
set up the new expected temporal reference and picture  
number for the incoming data. The middle state just sets  
the index to be arr\_buf so that the correct picture number  
register is updated (note that this\_pnum is also updated).  
10      Control then proceeds to state OUTPUT\_TAIL which outputs  
data (assuming favorable two-wire interface signals) until  
a low extension is encountered. At this point, the main  
loop is re-started. This means that whole data blocks (64  
items) are output, in between which, there are no tests for  
15      presentation flags or display requests.

A FLUSH token in the data stream indicates that sequence information (presentation number, picture number, rst\_fld) should be reset. This can only occur when all of the data leading up to the FLUSH has been correctly processed. Accordingly, it is necessary, having received a FLUSH, to monitor the status of all of the buffers until it is certain that all frames have been handed over to the display, i.e., all but one of the buffers have status EMPTY, and the other is IN\_USE (as the display buffer). At that point, a "new sequence" can safely be used.

When a FLUSH token is detected in state TOKEN, the flag from\_fl is set, causing the basic state machine loop to be changed such that state FLUSH is visited instead of state  
30 TOKEN. State FLUSH examines the status of each buffer in turn, waiting for it to become VACANT or IN\_USE as display. The state machine simply cycles around the loop until the condition is true, then increments its index and repeats the process until all of the buffers have been visited.  
35 When the last buffer fulfills the condition, presentation number, picture number, and all of the temporal reference registers assume their reset values rst\_fld is set to 1.

The flag from\_fl is reset and the normal main loop operation is resumed.

#### C.2.4.8 Operation When TEMPORAL\_REFERENCE Received

When a TEMPORAL\_REFERENCE token is encountered, a check  
 5 is made on the H.261 bit and, if set, the four states  
 TEMP\_REF0 to TEMP\_REF3 are visited. These perform the  
 following operations:

```

    TEMP_REF0:temp_ref=in_data_reg;
    TEMP_REF1:delta=temp_ref-exp_tr;index=arr_buf;
  10  TEMP_REF2:exp_tr=delta+exp_tr;
    TEMP_REF3:pic_num[i]=this_pnum+delta;index=1.
  
```

#### C.2.4.9 Other Tokens and Tails

State TOKEN passes control to state OUTPUT\_TAIL in all  
 cases other than those outlined above. Control remains  
 15 here until the last word of the token is encountered  
 (in\_extn\_reg is low) and the main loop is then re-entered.

#### C.2.5 Applications Notes

##### C.2.5.1 State Machine Stalling Buffer Manager Input

This requirement repeatedly check for the "asynchronous"  
 20 timing events of picture clock and display buffer request.  
 The necessity of having the buffer manager input stalled  
 during these checks means that when there is a continuous  
 supply of data at the input to the buffer manager, there  
 will be a restriction on the data rate through the buffer  
 25 manager. A typical sequence of states may be PRES0, PRES1,  
 DRQ, TOKEN, OUTPUT\_TAIL, each, with the exception of  
 OUTPUT\_TAIL, lasting one cycle. This means that for each  
 block of 64 data items, there will be an overhead of 3  
 cycles during which the input is stalled (during states  
 30 PRES0, PRES1 and DRQ) thereby slowing the write rate by  
 3/64 or approximately 5%. This number may occasionally  
 increase to up to 13 cycles of overhead when auxiliary  
 branches of the state machine are executed under worst-case  
 conditions. Note that such large overheads will only apply  
 35 on a once-per-frame basis.

##### C.2.5.2 Presentation Number Behavior During An Access

The particular embodiment of the bm\_pres illustrated by

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### C.3.1 Introduction

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### C.3.2 Functional Overview

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## Standard address sequence:

000,001,00C,00D,100,200;  
 002,003,00E,00F,101,201;  
 004,005,010,011,102,202;  
 006,007,012,013,103,203;  
 008,009,014,015,104,105;  
 00A,00B,016,017,105,205;  
 018,019,024,025,106,107;  
 01A,01B,026.....  
 .....

080,081,08C,08D,122,222;  
 082,083,08E,08F,123,223;

## H261-type sequence:

000,001,00C,00D,100,200;  
 002,003,00E,00F,101,201;  
 004,005,010,011,102,202;  
 018,019,024,025,106,107;  
 01A,01B,026,027,107,207;  
 01C,01D,028,029,108,208;  
 030,031,03C,03D,10C,20C,  
 032,033,03E,03F,10D,20D;  
 034,035,040,041,10E,20E;  
 006,007,012,013,103,203;  
 008,009,014,015,104,105;  
 00A,00B,016,017,105,205;  
 01E,01F,02A,02B,109,209;  
 020,021,02C,02D,10A,20A;

022,023,02E,02F,10B,20B;  
 036,037,042,043,10F,20F;  
 038,039,044,045,110,210;  
 03A,03B,046,047,111,211;  
 048,049,054,055,112,212;  
 04A,04B,056.....  
 .....  
 06A,06B,076,077,11D,21D;  
 07E,07F,08A,08B,121,221;  
 080,081,08C,08D,122,222;  
 082,083,08E,08F,123,223;

### C.3.3 Architecture

#### C.3.3.1 Interfaces

##### C.3.3.1.1 Interface to buffer manager

The buffer manager outputs data and the buffer index  
 5 directly to the write address generator. This is performed  
 under the control of a two-wire-interface. In some ways,  
 it is possible to consider the write address generator  
 block as an extension of the buffer manager because the two  
 are very closely linked. They do, however, operate from  
 10 two separate (but similar) clock generators.

##### C.3.3.1.2 Interface to dramif

The write address generator provides data and addresses  
 for the DRAM interface. Each of these has their own two-  
 wire-interface, and the dramif uses each of them in  
 15 different clock regimes. In particular, the address is  
 clocked into the dramif on a clock which is not related to  
 the write address generator clock. It is, therefore,  
 synchronized at the output.

##### C.3.3.1.3 Microprocessor Interface

20 The write address generator uses three bits of  
 microprocessor address space together with 8-bit data bus  
 and read and write strobes. There is a single select bit  
 for register access.

#### C.3.3.1.4 Events

The write address generator is capable of producing five different events. Two are in response to picture size information appearing in the data stream (hmbs and vmbs), and three are in response to DEFINE\_SAMPLING tokens (one event for each component).

#### C.3.3.2 Basic Structure

The structure of the write address generator is shown in the schematic waddrngen.sch. It comprises a datapath, some controlling logic, and snoopers and synchronization.

##### C.3.3.2.1 The Datapath (bwadpath)

The datapath is of the type described in Chapter C.5 of this document, comprising an 18-bit adder/subtractor and register file (see C.3.3.4), and producing a zero flag (based on the adder output) for use in the control logic.

##### C.3.3.2.2 The Controlling Logic

The controlling logic of the present invention consists of hardware to generate all of the register file load and drive signals, the adder control signals, the two-wire-interface signals, and also includes the writable control registers.

##### C.3.3.2.3 Snoopers and Synchronization

Super snoopers exist on both the data and address ports. Snoopers in the datapaths, controlled as super-snoopers from the zcells. The address has synchronization between the write address generator clock and the dramif's "clk" regime. Syncifs are used in the zcells for the two-wire interface signals, and simplified synchronizers are used in the datapath for the address.

#### C.3.3.3 Controlling Logic and State Machine

##### C.3.3.3.1 Input/Output Block (wa inout)

This block contains the input and two output two-wire interfaces, together with latches for the input data (for token decode) and arrival buffer index (for decoding four ways).

##### C.3.3.3.2 Two Cycle Control Block (wa fc)

The flag fc (first cycle) is maintained here and

00000000-00000000

indicates whether the state machine is in the middle of a two-cycle operation (i.e., an operation involving an add).

#### C.3.3.3.3. Component Count (wa comp)

Separate addresses are required for data blocks in each component, and this block maintains the current component under consideration based on the type of DATA header received in the input stream.

#### C.3.3.3.4 Modulo-3 Control (wa mod3)

When generating address sequences for H.261 data streams, it is necessary to count three rows of macroblocks to half way along the screen (see C.3.2). This is effected by maintaining a modulo-3 counter, incremented each time a new row of macroblocks is visited.

#### C.3.3.3.5 Control Registers (wa uregs)

Module wa\_uregs contains the setup register and the coding standard register - the latter is loaded from the data stream. The setup register uses 3 bits: QCIF (lsb) and the maximum component expected in the data stream (bits 1 and 2). The access bit also resides in this block (synchronized as usual), with the "stopped" bits being derived at the next level up the hierarchy (walogic) as the OR of the access bit and the event stop bits. Microprocessor address decoding is done by the block wa\_udec which takes read and write strobes, a select wire, and the lower two bits of the address bus.

#### C.3.3.3.6 Controlling State Machine (wa state)

The logic in this block is split into several distinct areas. The state decode, new state encode, derivation of "intermediate" logic signals, datapath control signals (drivea, driveb, load, adder controls and select signals), multiplexer controls, two-wire-interface controls, and the five event signals.

#### C.3.3.3.7 Event Generation

The five event bits are generated as a result of certain tokens arriving at the input. It is important that, in each case, the entire token is received before any events are generated because the event service routines perform

calculations based on the new values received. For this reason, each of the bits is delayed by a whole cycle before being input to the event hardware.

#### C.3.3.4 Register Address Map

- 5 There are two sets of registers in the write address generator block. These are the top-level setup type registers located in the standard cell section, and keyholed datapath registers. These are listed in Table C.3.1 and C.3.2, respectively.

| Register Name    | Address | Bits | Reset State | Function                               |
|------------------|---------|------|-------------|----------------------------------------|
| BU_WADDR_COD_STD | 0x4     | 2    | 0           | Cod std from data stream               |
| BU_WADDR_ACCESS  | 0x5     | 1    | 0           | Access bit                             |
| BU_WADDR_CTL1    | 0x6     | 3    | 0           | max component[2.1] and CCIF[0]         |
| BU_WA_ADDR_SNP2  | 0xB0    | 8    |             | snooper on the write address generator |
| BU_WA_ADDR_SNP1  | 0xB1    | 8    |             | address generator                      |
| BU_WA_ADDR_SNP0  | 0xB2    | 8    |             | address o/p.                           |
| BU_WA_DATA_SNP1  | 0xB4    | 8    |             | snooper on data output of              |
| BU_WA_DATA_SNP0  | 0xB5    | 8    |             | WA                                     |

| Keyhole Register Name      | Keyhole Address | Bits | Comments       |
|----------------------------|-----------------|------|----------------|
| BU_WADDR_BUFFER0_BASE_MSB  | 0x85            | 2    | Must be Loaded |
| BU_WADDR_BUFFER0_BASE_MID  | 0x86            | 8    |                |
| BU_WADDR_BUFFER0_BASE_LSB  | 0x87            | 8    |                |
| BU_WADDR_BUFFER1_BASE_MSB  | 0x89            | 2    | Must be Loaded |
| BU_WADDR_BUFFER1_BASE_MID  | 0x8a            | 8    |                |
| BU_WADDR_BUFFER1_BASE_LSB  | 0x8b            | 8    |                |
| BU_WADDR_BUFFER2_BASE_MSB  | 0x8d            | 2    | Must be Loaded |
| BU_WADDR_BUFFER2_BASE_MID  | 0x8e            | 8    |                |
| BU_WADDR_BUFFER2_BASE_LSB  | 0x8f            | 8    |                |
| BU_WADDR_COMP0_HMBADDR_MSB | 0x91            | 2    | Test only      |
| BU_WADDR_COMP0_HMBADDR_MID | 0x92            | 8    |                |
| BU_WADDR_COMP0_HMBADDR_LSB | 0x93            | 8    |                |
| BU_WADDR_COMP1_HMBADDR_MSB | 0x95            | 2    | Test only      |
| BU_WADDR_COMP1_HMBADDR_MID | 0x96            | 8    |                |
| BU_WADDR_COMP1_HMBADDR_LSB | 0x97            | 8    |                |
| BU_WADDR_COMP2_HMBADDR_MSB | 0x99            | 2    | Test only      |
| BU_WADDR_COMP2_HMBADDR_MID | 0x9a            | 8    |                |
| BU_WADDR_COMP2_HMBADDR_LSB | 0x9b            | 8    |                |
| BU_WADDR_COMP0_VMBADDR_MSB | 0x9d            | 2    | Test only      |
| BU_WADDR_COMP0_VMBADDR_MID | 0x9e            | 8    |                |
| BU_WADDR_COMP0_VMBADDR_LSB | 0x9f            | 8    |                |
| BU_WADDR_COMP1_VMBADDR_MSB | 0xa1            | 2    | Test only      |
| BU_WADDR_COMP1_VMBADDR_MID | 0xa2            | 8    |                |
| BU_WADDR_COMP1_VMBADDR_LSB | 0xa3            | 8    |                |
| BU_WADDR_COMP2_VMBADDR_MSB | 0xa5            | 2    | Test only      |
| BU_WADDR_COMP2_VMBADDR_MID | 0xa6            | 8    |                |
| BU_WADDR_COMP2_VMBADDR_LSB | 0xa7            | 8    |                |
| BU_WADDR_VBADDR_MSB        | 0xa9            | 2    | Test only      |
| BU_WADDR_VBADDR_MID        | 0xaa            | 8    |                |
| BU_WADDR_VBADDR_LSB        | 0xab            | 8    |                |

Table C.3.2 Image Formatter Address Generator Keyhole

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| Keyhole Register Name                   | Keyhole Address | Bits | Comments       |
|-----------------------------------------|-----------------|------|----------------|
| BU_WADDR_COMP0_HALF_WIDTH_IN_BLOCKS_MSB | 0xad            | 2    | Must be Loaded |
| BU_WADDR_COMP0_HALF_WIDTH_IN_BLOCKS_MID | 0xae            | 8    |                |
| BU_WADDR_COMP0_HALF_WIDTH_IN_BLOCKS_LSB | 0xaf            | 8    |                |
| BU_WADDR_COMP1_HALF_WIDTH_IN_BLOCKS_MSB | 0xb1            | 2    | Must be Loaded |
| BU_WADDR_COMP1_HALF_WIDTH_IN_BLOCKS_MID | 0xb2            | 8    |                |
| BU_WADDR_COMP1_HALF_WIDTH_IN_BLOCKS_LSB | 0xb3            | 8    |                |
| BU_WADDR_COMP2_HALF_WIDTH_IN_BLOCKS_MSB | 0xb5            | 2    | Must be Loaded |
| BU_WADDR_COMP2_HALF_WIDTH_IN_BLOCKS_MID | 0xb6            | 8    |                |
| BU_WADDR_COMP2_HALF_WIDTH_IN_BLOCKS_LSB | 0xb7            | 8    |                |
| BU_WADDR_HB_MSB                         | 0xb9            | 2    | Test only      |
| BU_WADDR_HB_MID                         | 0xba            | 8    |                |
| BU_WADDR_HB_LSB                         | 0xbb            | 8    |                |
| BU_WADDR_COMP0_OFFSET_MSB               | 0xbd            | 2    | Must be Loaded |
| BU_WADDR_COMP0_OFFSET_MID               | 0xbe            | 8    |                |
| BU_WADDR_COMP0_OFFSET_LSB               | 0xbf            | 8    |                |
| BU_WADDR_COMP1_OFFSET_MSB               | 0xc1            | 2    | Must be Loaded |
| BU_WADDR_COMP1_OFFSET_MID               | 0xc2            | 8    |                |
| BU_WADDR_COMP1_OFFSET_LSB               | 0xc3            | 8    |                |
| BU_WADDR_COMP2_OFFSET_MSB               | 0xc5            | 2    | Must be Loaded |
| BU_WADDR_COMP2_OFFSET_MID               | 0xc6            | 8    |                |
| BU_WADDR_COMP2_OFFSET_LSB               | 0xc7            | 8    |                |
| BU_WADDR_SCRATCH_MSB                    | 0xc9            | 2    | Test only      |
| BU_WADDR_SCRATCH_MID                    | 0xca            | 8    |                |
| BU_WADDR_SCRATCH_LSB                    | 0xcb            | 8    |                |
| BU_WADDR_MBS_WIDE_MSB                   | 0xcd            | 2    | Must be Loaded |
| BU_WADDR_MBS_WIDE_MID                   | 0xce            | 8    |                |
| BU_WADDR_MBS_WIDE_LSB                   | 0xcf            | 8    |                |
| BU_WADDR_MBS_HIGH_MSB                   | 0xd1            | 2    | Must be Loaded |
| BU_WADDR_MBS_HIGH_MID                   | 0xd2            | 8    |                |
| BU_WADDR_MBS_HIGH_LSB                   | 0xd3            | 8    |                |

Table C.3.2 Image Formatter Address Generator Keyhole

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| Keyhole Register Name                  | Keyhole Address | Bits | Comments       |
|----------------------------------------|-----------------|------|----------------|
| BU_WADDR_COMP0_LAST_MB_IN_ROW_MSB      | 0xd5            | 2    | Must be Loaded |
| BU_WADDR_COMP0_LAST_MB_IN_ROW_MID      | 0xd6            | 8    |                |
| BU_WADDR_COMP0_LAST_MB_IN_ROW_LSB      | 0xd7            | 8    |                |
| BU_WADDR_COMP1_LAST_MB_IN_ROW_MSB      | 0xd9            | 2    | Must be Loaded |
| BU_WADDR_COMP1_LAST_MB_IN_ROW_MID      | 0xda            | 8    |                |
| BU_WADDR_COMP1_LAST_MB_IN_ROW_LSB      | 0xdb            | 8    |                |
| BU_WADDR_COMP2_LAST_MB_IN_ROW_MSB      | 0xdd            | 2    | Must be Loaded |
| BU_WADDR_COMP2_LAST_MB_IN_ROW_MID      | 0xde            | 8    |                |
| BU_WADDR_COMP2_LAST_MB_IN_ROW_LSB      | 0xdf            | 8    |                |
| BU_WADDR_COMP0_LAST_MB_IN_HALF_ROW_MSB | 0xe1            | 2    | Must be Loaded |
| BU_WADDR_COMP0_LAST_MB_IN_HALF_ROW_MID | 0xe2            | 8    |                |
| BU_WADDR_COMP0_LAST_MB_IN_HALF_ROW_LSB | 0xe3            | 8    |                |
| BU_WADDR_COMP1_LAST_MB_IN_HALF_ROW_MSB | 0xe5            | 2    | Must be Loaded |
| BU_WADDR_COMP1_LAST_MB_IN_HALF_ROW_MID | 0xe6            | 8    |                |
| BU_WADDR_COMP1_LAST_MB_IN_HALF_ROW_LSB | 0xe7            | 8    |                |
| BU_WADDR_COMP2_LAST_MB_IN_HALF_ROW_MSB | 0xe9            | 2    | Must be Loaded |
| BU_WADDR_COMP2_LAST_MB_IN_HALF_ROW_MID | 0xea            | 8    |                |
| BU_WADDR_COMP2_LAST_MB_IN_HALF_ROW_LSB | 0xeb            | 8    |                |
| BU_WADDR_COMP0_LAST_ROW_IN_MB_MSB      | 0xed            | 2    | Must be Loaded |
| BU_WADDR_COMP0_LAST_ROW_IN_MB_MID      | 0xee            | 8    |                |
| BU_WADDR_COMP0_LAST_ROW_IN_MB_LSB      | 0xef            | 8    |                |
| BU_WADDR_COMP1_LAST_ROW_IN_MB_MSB      | 0xf1            | 2    | Must be Loaded |
| BU_WADDR_COMP1_LAST_ROW_IN_MB_MID      | 0xf2            | 8    |                |
| BU_WADDR_COMP1_LAST_ROW_IN_MB_LSB      | 0xf3            | 8    |                |
| BU_WADDR_COMP2_LAST_ROW_IN_MB_MSB      | 0xf5            | 2    | Must be Loaded |
| BU_WADDR_COMP2_LAST_ROW_IN_MB_MID      | 0xf6            | 8    |                |
| BU_WADDR_COMP2_LAST_ROW_IN_MB_LSB      | 0xf7            | 8    |                |
| BU_WADDR_COMP0_BLOCKS_PER_MB_ROW_MSB   | 0xf9            | 2    | Must be Loaded |
| BU_WADDR_COMP0_BLOCKS_PER_MB_ROW_MID   | 0xfa            | 8    |                |
| BU_WADDR_COMP0_BLOCKS_PER_MB_ROW_LSB   | 0xfb            | 8    |                |
| BU_WADDR_COMP1_BLOCKS_PER_MB_ROW_MSB   | 0xfd            | 2    | Must be Loaded |
| BU_WADDR_COMP1_BLOCKS_PER_MB_ROW_MID   | 0xfe            | 8    |                |
| BU_WADDR_COMP1_BLOCKS_PER_MB_ROW_LSB   | 0xff            | 8    |                |
| BU_WADDR_COMP2_BLOCKS_PER_MB_ROW_MSB   | 0x101           | 2    | Must be Loaded |
| BU_WADDR_COMP2_BLOCKS_PER_MB_ROW_MID   | 0x102           | 8    |                |
| BU_WADDR_COMP2_BLOCKS_PER_MB_ROW_LSB   | 0x103           | 8    |                |

Table C.3.2 Image formatter Address Generator Keyhole

00000000 00000000 00000000 00000000



| Keyhole Register Name          | Address | Bits | Comments       |
|--------------------------------|---------|------|----------------|
| BU_WADDR_COMP0_LAST_MB_ROW_MSB | 0x105   | 2    | Must be Loaded |
| BU_WADDR_COMP0_LAST_MB_ROW_MID | 0x106   | 8    |                |
| BU_WADDR_COMP0_LAST_MB_ROW_LSB | 0x107   | 8    |                |
| BU_WADDR_COMP1_LAST_MB_ROW_MSB | 0x109   | 2    | Must be Loaded |
| BU_WADDR_COMP1_LAST_MB_ROW_MID | 0x10a   | 8    |                |
| BU_WADDR_COMP1_LAST_MB_ROW_LSB | 0x10b   | 8    |                |
| BU_WADDR_COMP2_LAST_MB_ROW_MSB | 0x10d   | 2    | Must be Loaded |
| BU_WADDR_COMP2_LAST_MB_ROW_MID | 0x10e   | 8    |                |
| BU_WADDR_COMP2_LAST_MB_ROW_LSB | 0x10f   | 8    |                |
| BU_WADDR_COMP0_HBS_MSB         | 0x111   | 2    | Must be Loaded |
| BU_WADDR_COMP0_HBS_MID         | 0x112   | 8    |                |
| BU_WADDR_COMP0_HBS_LSB         | 0x113   | 8    |                |
| BU_WADDR_COMP1_HBS_MSB         | 0x115   | 2    | Must be Loaded |
| BU_WADDR_COMP1_HBS_MID         | 0x116   | 8    |                |
| BU_WADDR_COMP1_HBS_LSB         | 0x117   | 8    |                |
| BU_WADDR_COMP2_HBS_MSB         | 0x119   | 2    | Must be Loaded |
| BU_WADDR_COMP2_HBS_MID         | 0x11a   | 8    |                |
| BU_WADDR_COMP2_HBS_LSB         | 0x11b   | 8    |                |
| BU_WADDR_COMP0_MAXHB           | 0x11f   | 2    | Must be Loaded |
| BU_WADDR_COMP1_MAXHB           | 0x123   | 2    |                |
| BU_WADDR_COMP2_MAXHB           | 0x127   | 2    |                |
| BU_WADDR_COMP0_MAXVB           | 0x12b   | 2    | Must be Loaded |
| BU_WADDR_COMP1_MAXVB           | 0x12f   | 2    |                |
| BU_WADDR_COMP2_MAXVB           | 0x133   | 2    |                |

**Table C.3.2 Image Formatter Address Generator Keyhole**

The keyhole registers fall broadly into two categories. Those which must be loaded with picture size parameters prior to any address calculation, and those which contain running totals of various (horizontal and vertical) block and macroblock counts. The picture size parameters may be loaded in response to any of the interrupts generated by the write address generator, i.e., when any of the picture size or sampling tokens appear in the data stream. Alternatively, if the picture size is known prior to receiving the data stream, they can be written just after reset. Example setups are given in Sectionr C.13, and the picture size parameter registers are defined in the next section.

### C.3.4 Programming the Write Address Generator

The following datapath registers must contain the correct picture size information before address calculation can proceed. They are illustrated in Figure 162.

- 5        1) WADDR\_HALF\_WIDTH\_IN\_BLOCKS: this defines the  
         half width, in blocks, of the incoming picture.
- 2) WADDR\_MBS\_WIDE: this defines the width, in  
         macroblocks, of the incoming picture.
- 3) WADDR\_MBS\_HIGH: this defines the height, in  
10       macroblocks, of the incoming picture.
- 4) WADDR\_LAST\_MB\_IN\_ROW: this defines the block  
         number of the top left hand block of the  
         last macroblock in a single, full-width row  
         of macroblocks. block numbering starts at  
15       zero in the top left corner of the left-most  
         macroblock, increases across the frame  
         with each block and subsequently with each  
         following row of blocks within the  
         macroblock row.
- 20       5) WADDR\_LAST\_MB\_IN\_HALF\_ROW: this is similar  
         to the previous item, but defines the block  
         number of the top left block in the last  
         macroblock in a half-width row of  
         macroblocks.
- 25       6) WADDR\_LAST\_ROW\_IN\_MB: this defines the block  
         number of the left most block in the last  
         row of blocks within a row of macroblocks.
- 7) WADDR\_BLOCKS\_PER\_MB\_ROW: this defines the  
         total number of blocks contained in a  
30       single, full-width row of macroblocks.
- 8) WADDR\_LAST\_MB\_ROW: this defines the top  
         left block address of the left-most  
         macroblock in the last row of macroblocks  
         in the picture.
- 35       9) WADDR\_HBS: this defines the width in blocks  
         of the incoming picture.
- 10) WADDR\_MAXHB: this defines the block number

of the right-most block in a row of blocks in a single macroblock.

11)WADDR\_MAXVB: this defines the height-1, in blocks, of a single macroblock.

5 In addition, the registers defining the organization of the DRAM must be programmed. These are the three buffer base registers, and the n component offset registers, where n is the number of components expected in the data stream (it can be defined in the data stream; and can be 1 minimum and 3 maximum).

10 Note that many of the parameters specify block numbers or block addresses. This is because the final address is expected to be a block address, and the calculation is based on a cumulative algorithm.

15 The screen configuration illustrated in Figure 162 yields the following register values:

- 1)WADDR\_HALF\_WIDTH\_IN\_BLOCKS = 0x16
- 2)WADDR\_MBS\_WIDE = 0x16
- 3)WADDR\_MBS\_HIGH = 0x12
- 4)WADDR\_LAST\_MB\_IN\_ROW = 0x2A
- 5)WADDR\_LAST\_MB\_IN\_HALF\_ROW = 0x14
- 6)WADDR\_LAST\_ROW\_IN\_MB = 0x2C
- 7)WADDR\_BLOCKS\_PER\_MB\_ROW = 0x58
- 8)WADDR\_LAST\_MB\_ROW = 0x5D8
- 9)WADDR\_HBS = 0x2C
- 10)WADDR\_MAXVB = 1
- 11)WADDR\_MAXHB = 1

### C.3.5 Operation of The State Machine

There are 19 states in the buffer manager's state machine, as detailed in Table C.3.3. These interact as shown in Figure 164, and also as described in the behavioral description, bmlogic.M.

| State           | Value |
|-----------------|-------|
| IDLE            | 0x00  |
| DATA            | 0x10  |
| CODING_STANDARD | 0x0C  |
| HORZ_MBS0       | 0x07  |
| HORZ_MBS1       | 0x06  |
| VERT_MBS0       | 0x0B  |
| VERT_MBS1       | 0x0A  |
| OUTPUT_TAIL     | 0x08  |
| HB              | 0x11  |
| MB0             | 0x1D  |
| MB1             | 0x12  |
| MB2             | 0x1E  |
| MB3             | 0x13  |
| MB4             | 0x0E  |
| MB5             | 0x14  |
| MB6             | 0x15  |
| MB4A            | 0x18  |

Table C.3.3 Write Address Generator States

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| State   | Value |
|---------|-------|
| MB48    | 0x09  |
| MB4C    | 0x17  |
| MB4D    | 0x16  |
| ADDR1   | 0x19  |
| ADDR2   | 0x1A  |
| ADDR3   | 0x1B  |
| ADDR4   | 0x1C  |
| ADDR5   | 0x03  |
| HSAMP   | 0x05  |
| VSAMP   | 0x04  |
| PIC_ST1 | 0x0f  |
| PIC_ST2 | 0x01  |
| PIC_ST3 | 0x02  |

**Table C.3.3 Write Address Generator States**

#### C.3.5.1 Calculation of the Address

The major section of the write address generator state machine is illustrated down the left hand side of Figure 164. On receipt of a DATA token, the state machine moves from state IDLE to state ADDR1 and then through to state ADDR5, from which an 18-bit block address is output with two-wire-interface controls. The calculations performed by the states ADDR1 through to ADDR5 are:

```

10  BU_WADDR_SCRATCH=BU_BUFFERn_BASE
    +BU_COMPm_OFFSET;
    BU_WADDR_SCRATCH=BU_WADDR_SCRATCH
    +BU_WADDR_VMBADDR;
    BU_WADDR_SCRATCH=BU_WADDR_SCRATCH
15  +BU_WADDR_HMBADDR;
    BU_WADDR_SCRATCH=BU_WADDR_SCRATCH
    +BU_WADDR_VBADDR;
    out_addr=BU_WADDR_SCRATCH+BU_WADDR_HB;

```

The registers used are defined as follows:

- 20     1) BU\_WADDR\_VMBADDR: the block address (the top left block) of the left-most macroblock of the row of macroblocks in which the block whose address is being calculated is contained.

- 2) BU\_WADDR\_HMBADDR: the block address (top left block) of the top macroblock of the column of macroblocks in which the block whose address is being calculated is contained.
- 5      3) BU\_WADDR\_VBADDR: the block address, within the macroblock row, of the left-most block of the row of blocks in which the block whose address is being calculated is contained.
- 10     4) BU\_WADDR\_HB: the horizontal block number, within the macroblock, of the block whose address is being calculated.
- 5) BU\_WADDR\_SCRATCH: the scratch register used for temporary storage of intermediate results.

Considering Figure 163, and taking, for example, the calculation of the block whose address is 0x62D, the following sequence of calculations will take place;

```

SCRATCH=BUFFERn_BASE+COMPm_OFFSET; (assume 0)
SCRATCH=0+0x5D8;
SCRATCH=0x5D8+0x28;
20     SCRATCH=0x600+0x2C;
       block address=0x62C+1=0x62D;

```

The contents of the various registers are illustrated in the Figure.

#### C.3.5.2 Calculation of New Screen Location Parameters

25      When the address has been output, the state machine continues to perform calculations in order to update the various screen location parameters described above. The states HB and MBO through to MB6 do the calculations, transferring control at some point to state DATA from which the reminder of the DATA Token is output.

30      These states proceed in pairs, the first of a pair calculating the difference between the current count and its terminal value and, hence, generating a zero flag. The second of the pair either resets the register or adds a fixed (based on values in the setup registers derived from screen size) offset. In each case, if the count under consideration has reached its terminal value (i.e., the



#### C.3.5.2.1 Calculations for Standard (MPEG-style) Sequences

The sequence of operations is as follows (in which the zero flag is based on the output of the adder):

```

5      states HB and MBO:
      scratch = hb - maxhb;
      if (z)
          hb = 0;
      else
10      (
          hb = hb + 1
          new_state = DATA;
      )
      states MB1 and MB2:
15      scratch = vb_addr - last_row_in_mb;
      if (z)
          vb_addr = 0;
      else
      (
20          vb_addr = vb_addr + width_in_blocks;
          new_state = DATA;
      )
      states MB3 and MB4:
      scratch = hmb_addr - last_mb_in_row;
25      if (z)
          hmb_addr = 0;
      else
      (
          hmb_addr = hmb_addr + maxhb;
30          new_state = DATA;
      )
      states MB5 and MB6:
      scratch = vmb_addr - last_mb_row;
      if (!z)
35          vmb_addr = vmb_addr + blocks_per_mb_row;
      (vmb_addr is reset after a PICTURE_START token is
detected, rather than when the end of a picture is inferred

```



from the calculations).

#### C.3.5.2.2 Calculations for H.261 Sequences

The sequence for H.261 calculations diverges from the standard sequence at state MB4:

```

5      states HB and MB0:-as above
      states MB1 and MB2:-as above
      states MB3 and MB4:
      scratch = hmb_addr - last_mb_in_row;
      if (z & (mod3==2)) /*end of slice on right of screen*/
10     (
          hmb_addr - 0;
          new_state = MB5;
        )
      else if (z) /*end of row on right of screen*/
15     (
          hmb_addr = half_width_in_blocks;
          new_state = MB4A;
        )
      else
20     (
          scratch = hmb_addr - last_mb_in_half_row;
          new-state = MB4B;
      )

```

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```
new_state = DATA;
```

}

(

!

5

}

```
new_state = DATA;
```

states MB5and MB6:- as above

When a PICTURE\_START token is received, control passes to state PIC\_ST1 where the vb\_addr register (BU\_WADDR\_VBADDR) is reset to 0. Each of states PIC\_ST2 and PIC\_ST3 are then visited, once for each component, resetting hmb\_addr and vmb\_addr respectively. Control then returns, via state OUTPUT\_TAIL, to IDLE.

#### C.3.5.3 Operation on PICTURE\_START Token

When a PICTURE\_START token is received, control passes to state PIC\_ST1 where the vb\_addr register (BU\_WADDR\_VBADDR) is reset to 0. Each of states PIC\_ST2  
 5 and PIC\_ST3 are then visited, once for each component, resetting hmb\_addr and vmb\_addr, respectively. Control then returns, via state OUTPUT\_TAIL, to IDLE.

#### C.3.5.4 Operation on DEFINE\_SAMPLING Token

When a DEFINE\_SAMPLING token is received, the component  
 10 register is loaded with the least significant two bits of the input data. In addition, via states HSAMP and VSAMP, the maxhb and maxvb registers for that component are loaded. Furthermore, the appropriate define sampling event bit is triggered (delayed by one cycle to allow the whole  
 15 token to be written).

#### C.3.5.5 Operation on HORIZONTAL\_MBS and VERTICAL\_MBS

When each of HORIZONTAL\_MBS and VERTICAL\_MBS arrive, the 14-bit value contained in the token is written, in two cycles, to the appropriate register. The relevant event  
 20 bit is triggered, delayed by one cycle.

#### C.3.5.6 Other Tokens

The CODING\_STANDARD token is detected and causes the top-level BU\_WADDR\_COD\_STD register to be written with the input data. This is decoded and the nh261 flag (not H261)  
 25 is hardwired to the buffer manager block. All other tokens cause control to move to state OUTPUT\_TAIL, which accepts data until the token finishes. Note, however, that it does not actually output any data.

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## SECTION C.4 Read Address Generator



| Register Names    | Bus | Keyhole Address | Description                                           | Comments                                                              |
|-------------------|-----|-----------------|-------------------------------------------------------|-----------------------------------------------------------------------|
| BUFFER_BASE0      | A   | 0x00,01,02,03   | Block address of the start of each buffer.            | These registers must be loaded by the upi before operation can begin. |
| BUFFER_BASE1      | A   | 0x04,05,06,07   |                                                       |                                                                       |
| BUFFER_BASE2      | A   | 0x08,09,0a,0b   |                                                       |                                                                       |
| DISP_COMP_OFFSET0 | B   | 0x24,25,26,27   | Offsets from the buffer base to where reading begins. |                                                                       |
| DISP_COMP_OFFSET1 | B   | 0x28,29,2a,2b   |                                                       |                                                                       |
| DISP_COMP_OFFSET2 | B   | 0x2c,2d,2e,2f   |                                                       |                                                                       |
| DISP_VBS_COMP0    | B   | 0x30,31,32,33   | Numero of vertical blocks to be read                  |                                                                       |
| DISP_VBS_COMP1    | B   | 0x34,35,36,37   |                                                       |                                                                       |
| DISP_VBS_COMP2    | B   | 0x38,39,3a,3b   |                                                       |                                                                       |
| ADDR_HBS_COMP0    | B   | 0x3c,3d,3e,3f   | Number of horizontal blocks IN THE DATA               |                                                                       |
| ADDR_HBS_COMP1    | B   | 0x40,41,42,43   |                                                       |                                                                       |
| ADDR_HBS_COMP2    | B   | 0x44,45,46,4    |                                                       |                                                                       |
| LINE0             | A   | 0x0c,0d,0e,0f   | Current line address                                  | These registers are temporary locations used by dispaddr.             |
| LINE1             | A   | 0x10,11,12,13   |                                                       |                                                                       |
| LINE2             | A   | 0x14,15,16,17   |                                                       |                                                                       |
| DISP_VB_CNT_COMP0 | A   | 0x18,19,1a,1b   | Number of vertical blocks remaining to be read.       | Note: All registers are R/W from the upi                              |
| DISP_VB_CNT_COMP1 | A   | 0x1c,1d,1e,1f   |                                                       |                                                                       |
| DISP_VB_CNT_COMP2 | A   | 0x20,21,22,23   |                                                       |                                                                       |

Table C.3.4 Dispaddr Datapath Registers

### C.4.3 Dline Control Registers

The above operation is modified by the dispaddr control registers which are shown in the Table C.4.3 below.

| Register Name                                                                   | Address | Bits  | Reset State | Function                                                                                             |
|---------------------------------------------------------------------------------|---------|-------|-------------|------------------------------------------------------------------------------------------------------|
| LINES_IN_LAST_ROW0                                                              | 0x08    | [2:0] | 0x07        | These three registers determine the number of lines (out of 8) of the last row of blocks to read out |
| LINES_IN_LAST_ROW1                                                              | 0x09    | [2:0] | 0x07        |                                                                                                      |
| LINES_IN_LAST_ROW2                                                              | 0x0a    | [2:0] | 0x07        |                                                                                                      |
| DISPADDR_ACCESS                                                                 | 0x0b    | [0]   | 0x00        | Access bit for dispaddr                                                                              |
| DISPADDR_CTL0<br><br>See below for a detailed description of these control bits | 0x0c    | [1:0] | 0x0         | SYNC_MODE                                                                                            |
|                                                                                 |         | [2]   | 0x0         | READ_START                                                                                           |
|                                                                                 |         | [3]   | 0x1         | INTERLACED/PROG                                                                                      |
|                                                                                 |         | [4]   | 0x0         | LSB_INVERT                                                                                           |
|                                                                                 |         | [7:5] | 0x0         | LINE_RPT                                                                                             |
| DISPADDR_CTL1                                                                   | 0x0d    | [0]   | 0x1         | COMP0HOLD                                                                                            |

Dispaddr Control Registers

TABLE C.4.3 CONTROL REGISTERS

#### 5 C.4.3.1 LINES\_IN\_LAST\_ROW[component]

These three registers determine, for each component, the number of lines in the last row of blocks that are to be read. Thus, the height of the read window may be an arbitrary number of lines. This is a back-up feature since the top, left and right edges of the window are on block boundaries, and the output controller can clip (discard) excess lines.

#### 15 C.4.3.2 DISPADDR\_ACCESS

This is the access bit for the whole of dispaddr. On writing a "1" to this location, dispaddr is halted synchronously to the clocks. The value read back from the access bit will remain "0" until dispaddr has safely halted. Having reached this state, it is safe to perform asynchronous upi accesses to all the dispaddr registers.

Note that the upi is actively locked out from the datapath registers until the access bit is "1". In order for access to dispaddr to be achieved without disrupting the current display or datapath operation, access will only given and released under the following circumstances.

Stopping: Access will only be granted if the datapath has finished its current two cycle operation (if it were doing one), and the "safe" signal from the output controller is high. This signal represents the area on the screen below the display window and is programmed in the output controller (not dispaddr). Note: It is, therefore, necessary to program the output controller before trying to gain access to dispaddr.

Starting-Access will only be released when "safe" is high, or during vsync. This ensures that display will not start too close to the active window.

This scheme allows the controlling software to request access, poll until end of display, modify dispaddr, and release access. If the software is too slow and doesn't release the access bit until after vsync, dispaddr will not start until the next safe period. Border color will be displayed during this "lost" picture (rather than rubbish).

#### C.4.3.3 DISPADDR\_CTL0[7:0]

When reading the following descriptions, it is important to understand the distinction between interlaced data and an interlaced display.

Interlaced data can be of two forms. The Top-Level Registers supports field-pictures (each buffer contains one field), and frames (each buffer contains an entire frame - interlaced or not)

DISPADDR\_CTL0[7:0] contains the following control bits:  
SYNC\_MODE[1:0]

With an interlaced display, vsyncs referring to top and bottom fields are differentiated by the field\_info pin. In this context, field\_info = HIGH meaning the top field. These two control bits determine which vsyncs dispaddr will request a new display buffer from the buffer manager and,

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thus, synchronize the fields in the buffers (if the data were interlaced) with the fields on the display:

0:New Display Buffer On Top Field

1:Bottom Field

5 2:Both Fields

3:Both Fields

At startup, dispaddr will request a buffer from the buffer manager on every vsync. Until a buffer is ready, dispaddr will receive a zero (no display) buffer. When it  
10 finally gets a good buffer index, dispaddr has no idea where it is on the display. It may, therefore, be necessary to synchronize the display startup with the correct vsync.

READ\_START

15 For interlaced displays at startup, this bit determines on which vsync display will actually start. Furthermore, having received a display buffer index, dispaddr may "sit out" the current vsync in order to line up fields on the display with the fields in the buffer.

20 INTERLACED/PROGRESSIVE

0:Progressive

1:Interlaced

In progressive mode, all lines are read out of the display area of the buffer. In interlaced mode, only  
25 alternate lines are read. Whether reading starts on the first or second line depends on field\_info. Note that with (interlaced) field-pictures, the system wants to read all lines from each buffer so the setting of this bit would be progressive. The mapping between field\_info and  
30 first/second line start may be inverted by lsb\_invert (so named for historical reasons).

LSB\_INVERT

When set, this bit inverts the field\_info signal seen by the line counter. Thus, reading may be started on the  
35 correct line of a frame and aligned to the display regardless of the convention adopted by the encoder, the display or the Top-Level Registers.

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Each bit, when set, causes the lines of the corresponding component to be read twice (bit 0 affects component 0 etc.). This forms the first part of the vertical unsampling. It is used in the 8 times chroma upsampling required for conversion from QFIF to 601.

This bit is used to program the ratio of the number of lines to be read (as opposed to displayed) for component 0 to those of components 1 and 2).

1: Twice as many component 0 lines, i.e., 4:2:0.

15 When passed a line address, these blocks generate a series of page/line addresses and blocks to read along the line. The minimum page width of 8 blocks is always assumed and the resulting outputs consist of a page address, a 3 bit line number, a 3 bit block start, and a 3 bit block  
20 stop address. (The line number is calculated by dline and passed through the dramctls unmodified). Thus, to read out 48 pixels of line 5 form page 0xaa starting from the third block from the left (an arbitrary point along an arbitrary line), the addresses passed to the DRAM interface would be:

Each of these three machines has 5 datapath registers.

30 These are shown in Table C.3.4. The basic behavior of each  
dramctl is:

Block start = 2

Block stop = 7

Each of these three machines has 5 datapath registers. These are shown in Table C 3.4 .

The basic behaviour of each dramctl is:-

```
while (true)
{
  CNT_LEFT = 0;
  GET_A_NEW_LINE_ADDRESS from dline;
  BLOCK_ADDR = input_block_addr + 0;
  PAGE_ADDR = input_page_addr + 0;
  CNT_LEFT = DISP_HBS + 0;
  while (CNT_LEFT > BLOCKS_LEFT)
  {
    BLOCKS_LEFT = 8 - BLOCK_ADDR;
    --> output PAGE_ADDR, start=BLOCK_ADDR, stop=7.
    PAGE_ADDR = PAGE_ADDR + 1;
    BLOCK_ADDR = 0;
    CNT_LEFT = CNT_LEFT - BLOCKS_LEFT;
  }
  /* Last Page of line */
  CNT_LEFT = CNT_LEFT + BLOCK_ADDR;
  CNT_LEFT = CNT_LEFT - 1;
  --> output PAGE_ADDR, start=BLOCK_ADDR, stop=CNT_LEFT
}
```

Table C.3.5 Dramctl(0,1 &amp;2) Datapath Registers

Table C.3.5 Dramctl(0,1 &amp;2) Datapath Registers

| Register Names | Bus | Keyhole Address | Description                                               | Comments                                                  |
|----------------|-----|-----------------|-----------------------------------------------------------|-----------------------------------------------------------|
| DISP_COMP0_HBS | A   | 0x48,49,4a,4b   | The number of horizontal blocks to be read, c.f. ADDR_HBS | This register must be loaded before operation can begin.  |
| DISP_COMP1_HBS | A   | 0x4c,4d,4e,4f   |                                                           |                                                           |
| DISP_COMP2_HBS | A   | 0x50,51,52,53   |                                                           |                                                           |
| CNT_LEFT0      | A   | 0x54,55,56,57   | Number of blocks remaining to be read                     | These registers are temporary locations used by dispaddr. |
| CNT_LEFT1      | A   | 0x58,59,5a,5b   |                                                           |                                                           |
| CNT_LEFT2      | A   | 0x5c,5d,5e,5f   |                                                           |                                                           |
| PAGE_ADDR0     | A   | 0x60,61,62,63   | The address of the current page.                          | Note: All registers are R/W from the upi                  |
| PAGE_ADDR1     | A   | 0x64,65,66,67   |                                                           |                                                           |
| PAGE_ADDR2     | A   | 0x68,69,6a,6b   |                                                           |                                                           |
| BLOCK_ADDR0    | B   | 0x6c,6d,6e,6f   | Current block address                                     |                                                           |
| BLOCK_ADDR1    | B   | 0x70,71,72,73   |                                                           |                                                           |
| BLOCK_ADDR2    | B   | 0x74,75,76,77   |                                                           |                                                           |
| BLOCKS_LEFT0   | B   | 0x78,79,7a,7b   | Blocks left in current page                               |                                                           |
| BLOCKS_LEFT1   | B   | 0x7c,7d,7e,7f   |                                                           |                                                           |
| BLOCKS_LEFT2   | B   | 0x80,81,82,83   |                                                           |                                                           |

## Programming

The following 15 dispaddr registers must be programmed before operation can begin.

BUFFER\_BASE0,1,2

DISP\_COMP\_OFFSET0,1,2

DISP\_VBS\_COMP0,1,2

ADDR\_HBS\_COMP0,1,2

DISP\_COMP0,1,2\_HBS

10

## Windowing with the Read Address Generator

15

20

```

BUFFER_BASE0 = 0x00
DISP_COMP_OFFSET0 = 0x2D
DISP_VBS_COMPO = 0x22
ADDR_HBS_COMPO = 0x2C
DISP_HBS_COMO = 0x2A

```

**Notes:**

- 35

## SECTION C.5 Datapaths for Address Generation

The datapaths used in dispaddr and waddrgen are identical in structure and width (18 bits), only differing in the number of registers, some masking, and the flags returned to the state machine. The circuit of one slice is shown in Figure 165, "Slice Of Datapath,". Registers are uniquely assigned to drive the A or B bus and their use (assignment) is optimized in the controller. All registers are loadable from the C bus, however, not all "load" signals are driven. All operations involving the adder cover two cycles allowing the adder to have ordinary ripple carry. Figure 166, "Two cycle operation of the datapath," shows the timing for the two cycle sum of two registers being loaded back into the "A" bus register. The various flags are "phO"ed within the datapath to allow ccode generation. For the same reason, the structure of the datapath schematics is a little unusual. The tristates for all the registers (onto the A and B buses) are in a single block which eliminates the combinatorial path in the cell, therefore, allowing better ccode generation. To gain upi access to the datapaths, the access bit must be set, for without this, the upi is locked out. Upi access is different from read and write:

25 •Writing: When the access bit is set, all load signals are disabled and one of a set of three byte addressed write strobes driven to the appropriate byte of one of the registers. The upi data bus passes vertically down the datapath (replicated, 2-8-8 bits) and the 18 bit register is written as three separate byte writes

30 •Reading: This is achieved using the A and B buses. Once again, the access bit must be set. The addressed register is driven onto the A or B bus and a upi byte select picks a byte from the relevant bus and drives it onto the upi bus.

35       As double cycle datapath operations require the A and B  
buses to retain their values, and upi accesses disrupt

All datapath registers in both address generators are addressed through a 9 bit wide keyhole at the top level address 0x28 (msb) and 0x29 (lsb) for the keyhole, and 0x2A for the data. The keyhole addresses are given in Table C.11.2.

```

10      1) All address registers in the address
      generators (dispaddr and waddrngen) contain
      blocked addresses. Pixel addresses are never
      used and the only registers containing line
      addresses are the three LINES_IN_LAST_ROW
      registers.
15      2) Some registers are duplicated between the
      address generators, e.g., BUFFER_BASE0 occurs
      in the address space for dispaddr and
      waddrngen. These are two separate registers
      which BOTH need loading. This allows display
20      windowing (only reading a portion of the
      display store), and eases the display of
      formats other than 3 component video.

```





the DRAM, one for each of Luminance (Y) and the Red and Blue color difference data (Cr and Cb, respectively).

The operation of a generic DRAM Interface is described in the Spacial Decoder document. The following section describes those features of the DRAM Interface, in accordance with the present invention, peculiar to the Video Formatter.

#### C.6.2 The Video Formatter DRAM Interface

In the video formatter, data is written into the external DRAM in blocks, but read out in raster order. Writing is exactly the same as already described for the Spacial Decoder, but reading is a little more complex.

The data in the Video Formatter external DRAM is organized so that at least 8 blocks of data fit into a single page. These 8 blocks are 8 consecutive horizontal blocks. When rasterizing, 8 bytes need to be read out of each of 8 consecutive blocks and written into the swing buffer (i.e., the same row in each of the 8 blocks).

Considering the top row (and assuming a byte-wide interface), the x address (the three LSBs) is set to zero, as is the y address (3 MSBs). The x address is then incremented as each of the first 8 bytes are read out. At this point, the top part of the address (bit 6 and above - LSB = bit 0) is incremented and the x address (3 LSBs) is reset to zero. This process is repeated until 64 bytes have been read. With a 16 or 32 bit wide interface to the external DRAM, the x address is merely incremented by two or four instead of by one.

The address generator can signal to the DRAM Interface that less than 64 bytes should be read (this may be required at the beginning or end of a raster line) although a multiple of 8 bytes is always read. This is achieved by using start and stop values. The start value is used for the top part of the address (bit 6 and above), and the stop value is compared with this and a signal generated which indicates when reading should stop.

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## SECTION C.7 Vertical Upsampling

### C.7.1 Introduction

Given a raster scan of pixels of one color component at its input, the vertical upsampler in accordance with the present invention, can provide an output scan of twice the height. Mode selection allows the output pixel values to be formed in a number of ways.

### C.7.2 Ports

Input two wire interface:

- 10 •in\_valid
- in\_accept
- in\_data[7:0]
- in\_lastpel
- in\_lastline

15 Output two wire interface:

- out\_valid
- out\_accept
- out\_data[9:0]
- out\_last

20 mode[2:0]

nupdata[7:0], upaddr, upsel[3:0], uprstr, upwstr

ramtest

tdin, tdout, tph0, tckm, tcks

ph0, ph1, notrst0

### 25 C.7.3 Mode

As selected by the input bus mode[2:0].

Mode register values 1 and 7 are not used.

In each of the above modes, the output pixels are represented as 10-bit values, not as bytes. No rounding or truncation takes place in this block. Where necessary, values are shifted left to use the same range.

#### C.7.3.1 Mode 0:Fifo

The block simply acts as a FIFO store. The number of output pixels is exactly the same as at the input. The values are shifted left by two.

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length of the line in "FIFO" mode.

The input signals in\_lastpel and in\_lastline are used to indicate the end of the input line and the end of the picture. In\_lastpel, it should be high coincident with the last pixel of each line. In\_lastline, it should be high coincident with the last pixel of the last line of the picture.

The output signal out\_last is high coincident with the last pixel of each output line.

In "repeat" mode, each line is written into store "a". The line is then read out twice. As it is read out for the second time, the next line may start to be written.

In "lower", "upper" and "central" modes, lines are written alternately into stores "a" and "b". The first line of a picture is always written into store "a". Two tiny state machines, one for each store, keep track of what is in each store and which output line is being formed. From these states are generated the read and write requests to the linestore RAMs, and the signals that determine when the next line may overwrite the present data.

A register (lastaddr) stores the write address when in\_lastpel is high, thereby providing the length of the line for the formation of the output lines.

C.7.5 UPI

This block contains two 512 x 8 bit RAM arrays, which may be accessed via the microprocessor interface in the typical way. There are no registers with microprocessor access.

## SECTION C.8 The Horizontal Up-Samplers

### C.8.1 Overview

In the present invention, top-Level Registers contain three identical Horizontal Up-samplers, one for each color component. All three are controlled independently and, therefore, only one need be described here. From the user's point of view, the only difference is that each Horizontal Up-sampler is mapped into a different set of addresses in the memory map.

The Horizontal Up-sampler performs a combined replication and filtering operation. In all, there are four modes of operation:

**Table C.7.1 Horizontal Up-sampler Modes**

| Mode | Function                                           |
|------|----------------------------------------------------|
| 0    | Straight-through (no processing). The reset state. |
| 1    | No up-sampling, filter using a 3-tap FIR filter.   |
| 2    | x2 up-sampling and filtering                       |
| 3    | x4 up-sampling and filtering                       |

### C.8.2 Using a Horizontal Up-Sampler

The address map for each Horizontal Up-sampler consists of 25 locations corresponding to 12 13-bit coefficient registers and one 2-bit mode register. The number written to the mode register determines the mode of operation, as outlined in Table C.7.1. Depending on the mode, some or all of the coefficient registers may be used. The equivalent FIR filter is illustrated below.

Depending on the mode of operation, the input,  $x_n$ , is held constant for one, two or four clock periods. The actual coefficients that are programmed for each mode are as follows:

Table C.7.2 Coefficients for Mode 1

| Coeff | All clock periods |
|-------|-------------------|
| k0    | c00               |
| k1    | c10               |
| k2    | c20               |

Table C.7.3 Coefficients for Mode 2

| Coeff | 1st clock period | 2nd clock period |
|-------|------------------|------------------|
| k0    | c00              | c01              |
| k1    | c10              | c11              |
| k2    | c20              | c21              |

Table C.7.4 Coefficients for Mode 3

| Coeff | 1st clock period | 2nd clock period | 3rd clock period | 4th clock period |
|-------|------------------|------------------|------------------|------------------|
| k0    | c00              | c01              | c02              | c03              |
| k1    | c10              | c11              | c12              | c13              |
| k2    | c20              | c21              | c22              | c23              |

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Coefficients which are not used in a particular mode need not be programmed when operating in that mode.

In order to achieve symmetrical filtering, the first and last pixels of each line are repeated prior to filtering.

5 For example, when up-sampling by two, the first and last pixels of each line are replicated four times rather than two. Because residual data in the filter is discarded at the end of each line, the number of pixels output is still always exactly one, two or four times the number in the  
10 input stream.

Depending on the values of the coefficients, output samples can be placed either coincident with or shifted from the input samples. Following are some example values for coefficients in some sample modes. A "-" indicates  
15 that the value of the coefficient is "don't care." All values are in hexadecimal.

Table C.7.5 Sample Coefficients

| Coefficient | x2 up-sample, o/p pels<br>coincident with Vp | x2 up-sample, o/p pels in<br>between Vp | x4 up-sample, o/p pels in<br>between Vp |
|-------------|----------------------------------------------|-----------------------------------------|-----------------------------------------|
| c00         | 0000                                         | 01BD                                    | 00E9                                    |
| c01         | 0000                                         | 010B                                    | 00B6                                    |
| c02         | -                                            | -                                       | 012A                                    |
| c03         | -                                            | -                                       | 0102                                    |
| c10         | 0800                                         | 0538                                    | 0661                                    |
| c11         | 0400                                         | 0538                                    | 0661                                    |
| c12         | -                                            | -                                       | 0446                                    |
| c13         | -                                            | -                                       | 029F                                    |
| c20         | 0000                                         | 010B                                    | 00E6                                    |
| c21         | 0400                                         | 01BD                                    | 00E9                                    |
| c22         | -                                            | -                                       | 0290                                    |
| c23         | -                                            | -                                       | 045F                                    |

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### C.8.3 Description of a Horizontal Up-Sampler

The datapath of the Horizontal Up-sampler is illustrated in Figure 168.

The operation is outlined below for the x4 upsample case.

5 In addition, x2 upsampling and x1 filtering (modes 2 and 1) are degenerate cases of this, and bypass (mode 0) the entire filter, data passing straight from the input latch to the output latch via the final mux, as illustrated.

```

1)When valid data is latched in the input
10 latch ("L"), it is held for 4 clock periods.

```

2) The coefficient registers (labelled "COEFF") are multiplexed onto the multipliers for one clock period, each in turn, at the same time as the two sets of four pipeline registers (labelled "PIPE") are clocked. Thus, for input data  $x_n$ , the first PIPE will fill up with the values  $COO.x_n$ ,  $CO1.x_n$ ,  $CO2.x_n$ ,  $CO3.x_n$ .

3) Similarly, the second multiplier will multiply  $x_2$  by all its coefficients, in turn, and the third multiplier by all its coefficients, in turn.

It can be seen that the output will be of the form shown in Table C.7.6

**Table C.7.6 Output Sequence for Mode 3**

| Clock Period | Output                                |
|--------------|---------------------------------------|
| 0            | $c20.x_n + c10.x_{n-1} + c00.x_{n-2}$ |
| 1            | $c21.x_n + c11.x_{n-1} + c01.x_{n-2}$ |
| 2            | $c22.x_n + c12.x_{n-1} + c02.x_{n-2}$ |
| 3            | $c23.x_n + c13.x_{n-1} + c03.x_{n-2}$ |

From the point of view of the output, each clock period  
25 produces an individual pixel. Since each output pixel is  
dependent on the weighted values of 12 input pixels  
(although there are only three different values), this can









In the CSC design, the precision of the coefficients was chosen so that, for 9 bit data, all output values were within plus or minus 1 bit of the values produced by a full floating point simulation of the algorithm (this is the best accuracy that it is possible to achieve). This gave 13 bit twos-complement coefficients for cx0-cx3 and 14 bit twos-complement coefficients for cx4. The coefficients for all the design conversions are given below in both decimal and hex.

[illegible]

|       | $E_a \rightarrow Y$ |      | $R \rightarrow Y$ |     | $Y \rightarrow E_a$ |      | $Y \rightarrow R$ |      |
|-------|---------------------|------|-------------------|-----|---------------------|------|-------------------|------|
| Coeff | Dec                 | Hex  | Dec               | Hex | Dec                 | Hex  | Dec               | Hex  |
| c01   | 0.299               | 0132 | 0.256             |     | 1.0                 | 0400 | 1.159             | 04AD |
| c02   | 0.527               | 0259 | 0.502             |     | 1.402               | 059C | 1.539             | 068E |
| c03   | 0.114               | 0075 | 0.098             |     | 0.0                 | 0000 | 0.0               | 0000 |
| c04   | 0.0                 | 0000 | 16                |     | -179.456            | F4C8 | -223.473          | F1B3 |
| c11   | 0.5                 | 0200 | 0.428             |     | 1.0                 | 0400 | 1.159             | 04AD |
| c12   | -0.419              | FE53 | -0.358            |     | -0.714              | FD25 | -0.935            | FOA9 |
| c13   | -0.081              | FFAD | -0.070            |     | -0.344              | FEA0 | -0.402            | FEB4 |
| c14   | 128.0               | 0800 | 128               |     | 135.5               | 0878 | 139.7             | 08BA |
| c21   | -0.169              | FF53 | -0.144            |     | 1.0                 | 0400 | 1.159             | 04AD |
| c22   | -0.331              | FEA0 | -0.293            |     | 0.0                 | 0000 | 0.0               | 0000 |
| c23   | 0.5                 | 0200 | 0.427             |     | 1.772               | 0717 | 2.071             | 0849 |
| c24   | 128                 | 0800 | 128               |     | -225.816            | F1D2 | -293.84           | EE42 |

15

$$Y = 0.299E_R + 0.587E_G + 0.0114E_B$$

and the following color-difference equations:

$$C_R = E_R - Y$$

$$C_B = E_B - Y$$

The equations in R, G and B are derived from these after the full-scale ranges of these quantities are considered.

### C.9.2 Using the Color-Space Converter

On reset, c01, c12, and c23 are set to 1 and all other  
 5 coefficients are set to 0. Thus,  $y_0=x_0$ ,  $y_1=x_1$  and  $y_2=x_2$   
 and all data is passed through unaltered. To select a  
 color-space conversion, simply write the appropriate  
 coefficients (from Table C.8.1, for example) into the  
 locations specified in the address map.

10 Referring to the schematics,  $x_{0..2}$  correspond to  
 $in\_data_{0..2}$  and  $y_{0..2}$  correspond to  $out\_data_{0..2}$ . Users  
 should remember that input data to the CSC must be up-  
 sampled to 4:4:4. If this is not the case, not only will  
 the color-space transforms have no meaning, but the chip  
 15 will lock.

It should be noted that each output can be formed from  
 any allowed combination of coefficients and inputs plus (or  
 minus) a constant. Thus, for any given color-space  
 conversion, the order of the outputs can be changed by  
 20 swapping the rows in the transform matrix (i.e., the  
 addresses into which the coefficients are written).

The CSC is guaranteed to work for all the transforms in  
 Table C.8.1. If other transforms are used the user must  
 remember the following:

- 25 1) The hardware will not work if any intermediate result  
 in the calculation requires greater than 10 bits of  
 precision (excluding the sign bit).
- 2) The output of the CSC is saturated to 0 and 511. That  
 is, any number less than 0 is replaced with 0 and any  
 30 number more than 511 is replaced with 511. The  
 implementation of the saturation logic assumes that the  
 results will only be slightly above 511 or slightly  
 below 0. If the CSC is programmed incorrectly, then a  
 common symptom will be that the output appears to  
 35 saturate all (or most of) the time.

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The structure of the CSC is illustrated in Figure 169, where only two of the three "components" have been shown because of space limitations. In the Figure, "register" or "R" implies a master-slave register and "latch" or "L" implies a transparent latch.

```

1)Data arrives at inputs x0-2 (in_data0-2). This
represents a single pixel in the input color-space.
This is latched.
15 2)x0 is multiplied by c01 and latched into the first
pipeline register. x1 and x2 move on one register.
3)x1 is multiplied by c02, added to (x1.c01) and latched
into the next pipeline register. x2 moves on one
register.
20 4)x2 is multiplied by c03 and added to the result of
(3), producing (x1.c01 + x2.c02 + x3.c03). The result
is latched into the next pipeline register.
5)The result of (4) is added to c04. Since data is kept
in carry-save format through the multipliers, this adder
25 is also used to resolve the data from the multiplier
chain. The result is latched in the next pipeline
register.
6)The final operation is to saturate the data. Partial
results are passed from the resolving adder to the
30 saturate block to achieve this.

```

Three multipliers are used, with the coefficients as the  
35 multiplicand and the data as the multiplier. This  
allows an efficient layout to be achieved, with partial  
results flowing down the datapath and the same input data

To achieve the reset state described in Section C.9.2, each of the three "components" must be reset in a different way. In order to avoid having three sets of schematics and three slightly different layouts, this is achieved by having inputs to the UPI registers which are tied high or low at the top level.

The output of the CSC contain re-synchronizing latches because the next function in the output pipe runs off a different clock generator.

## SECTION C.10 Output Controller



### C.10.3.2 Modes 1 and 2

These modes present 4:2:2 YCrCb. Assuming in\_data[23:16] is Y, in\_data[15:8] is Cr and in\_data[7:0] is Cb.

#### C.10.3.2.1 Mode 1

- 5 In 16-bit YCrCb, Y is presented on out\_data[15:8]. Cr and Cb are time multiplexed on out\_data[7:0], Cb first. Out\_data[23:16] is not used.

#### C.10.3.2.2 Mode 2

- 10 In 8-bit YCrCb, Y,Cr and Cb are time multiplexed on out\_data[7:0] in the order Cb, Y, Cr, Y. Out\_data[23:8] is not used.

### C.10.3.3 Output Timing

The following registers are used to place the data in a video display window.

- 15 •vdelay - The number of hsync pulses following a vsync pulse before the first line of video or border.  
 •hdelay - The number of clock cycles between hsync and the first pixel of video or border.  
 •height - The height of the video window, in lines.  
 20 •width - The width of the video window, in pixels.  
 •north, south - The height of the border, respectively, above and below the video window, in lines.  
 •west, east - The width of the border, respectively, to the left and to the right of the video window, in pels.

- 25 The minimum vdelay is zero. The first hsync is the first active line. The minimum value that can be programmed into hdelay is 2. Note, however, that the actual delay from in\_hsync to the first active output pixel is hdelay+1 cycles.

- 30 Any edge of the border can have the value zero. The color of the border is selected by writing to the registers border\_r, border\_g and border\_b. The color of the area outside the border is selected by writing to the registers blank\_r, blank\_g and blank\_b. Note that the multiplexing  
 35 performed in output modes 1 and 2 will also affect the border and blank.components. That is, the values in these registers correspond with in\_data[23:16], in\_data[15:8] and

in\_data [7:0].

#### C.10.4 Output Flags

- out\_active indicates that the output data is part of the active window, i.e., video data or border.
- 5   •out\_window indicates that the output data is part of the video window.
- out\_comp[1:0] indicates which color component is present on out\_data[7:0] in output modes 1 and 2. In mode 1, 0=Cb, 1=Cr. In mode 2, 0=Y, 1=Cr, 2=Cb.

#### 10   C.10.5 Two-Wire Mode

- The two-wire mode of the present invention is selected by writing 1 to the two wire register. It is not selected following reset. In two wire mode, the output timing registers and sync signals are ignored and the flow of data
- 15 through the block is controlled by out\_accept. Note that in normal operation, out\_accept should be tied high.

#### C.10.6 Snooper

There is a super-snooper on the output of the block which includes access to the output flags.

#### 20   C.10.7 How It Works

- Two identical down-counters keep track of the current position in the display. "Vcount" decrements on hsyncs and loads from the appropriate timing register on vsync or at its terminal count. "Hcount" decrements on every pixel and
- 25 loads on hsync or at its terminal count. Note that in output mode 2, one pixel corresponds to two clock cycles.

## SECTION C.11 The Clock Dividers

### C.11.1 Overview

Top-Level Registers in the present invention contain two identical Clock Dividers, one to generate a PICTURE\_CLK and one to generate an AUDIO\_CLK. The Clock Dividers are identical and are controlled independently. Therefore, only one need be described here. From the user's point of view, the only difference is that each Clock Divider's divisor register is mapped into a different set of addresses in the memory map.

The Clock Divider's function is to provide a 4X sysclk divided clock frequency, with no requirement for an even mark-space ratio.

The divisor is required to lay in the range -0 to ~16,000,000 and, therefore, it can be represented using 24bits with the restriction that the minimum divisor be 16. This is because the Clock Divider will approximate an equal mark-space ratio (to within one sysclk cycle) by using divisor/2. As the maximum clock frequency available is sysclk, the maximum divided frequency available is sysclk/2. Furthermore, because four counters are used in cascade divisor/2 must never be less than 8, else the divided clock output will be driven to the positive power rail.

### C.11.2 Using a Clock Divider

The address map for each Clock Divider consists of 4 locations corresponding to three 8-bit divisor registers and one 1-bit access register. The Clock Divider will power-up inactive and is activated by the completion of an access to its divisor register.

The divisor registers may be written in any order according to the address map in Table C.10.1. The Clock Divider is activated by sensing a synchronized 0 to 1 transition in its access bit. The first time a transition is sensed, the Clock Divider will come out of reset and generate a divided clock. Subsequent transitions (assuming

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the divisor has also been altered) will merely cause the Clock Divider to lock to its new frequency "on-the-fly." Once activated, there is no way of halting the Clock Divider other than by Chip RESET.

5

**Table C.10.1 Clock Divider Registers**

| Address | Register    |
|---------|-------------|
| 00b     | access bit  |
| 01b     | divisor MSB |
| 10b     | divisor     |
| 11b     | divisor LSB |

Any divisor value in the range 16 to 16,777,216 may be used.

#### C.11.3 Description of the Clock Divider

The Clock Divider is implemented as four 22 bit counters which are cascaded such that as one counter carries, it will activate the next counter in turn. A counter will count down the value of divisor/4 before carrying and, therefore, each counter will take it, in turn, to generate a pulse of the divided clock frequency.

After carrying, the counter will reload with divisor/8 and this is counted down to produce the approximate equal mark-space ratio divided clock. As each counter reloads from the divisor register when it is activated by the previous counter, this enables the divided clock frequency to be changed on the fly by simply altering the contents of the divisor.

Each counter is clocked by its own independent clock generator in order to control clock skew between counters precisely and to allow each counter to be clocked by a different set of clocks.

A state machine controls the generation of the divisor/4 and divisor/8 values and also multiplexes the correct source clocks from the PLL to the clock generators. The

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5

#### C.11.4 Testing the Clock Divider

10

The Clock Divider has been designed with full scan and, thus, may subsequently be tested using standard JTAG access, as long as the Chip has been powered up as above.

15

normal operation.

## SECTION C.12 Address Maps

### C.12.1 Top Level Address Map

Notes:-

- 5 1)The register for the Top Level Address Map as set forth in Table C.11.1 are the names used during the design. They are not necessarily the names that will appear on the datasheet.
- 2)Since this is a full address map, many of the locations listed here include locations for test only.

| REGISTER NAME                  | Address | Bits | COMMENT          |
|--------------------------------|---------|------|------------------|
| BU_EVENT                       | 0x0     | 8    | Write 1 to reset |
| BU_MASK                        | 0x1     | 8    | R/W              |
| BU_EN_INTERRUPTS               | 0x2     | 1    | R/W              |
| BU_WADDR_COD_STO               | 0x4     | 2    | R/W              |
| BU_WADDR_ACCESS                | 0x5     | 1    | R/W- access      |
| BU_WADDR_CTL1                  | 0x6     | 3    | R/W              |
| BU_DISPADDR_LINES_IN_LAST_ROW0 | 0x8     | 3    | R/W              |
| BU_DISPADDR_LINES_IN_LAST_ROW1 | 0x9     | 3    | R/W              |
| BU_DISPADDR_LINES_IN_LAST_ROW2 | 0xa     | 3    | R/W              |
| BU_DISPADDR_ACCESS             | 0xb     | 1    | R/W- access      |
| BU_DISPADDR_CTL0               | 0xc     | 8    | R/W              |
| BU_DISPADDR_CTL1               | 0xd     | 1    | R/W              |
| BU_BM_ACCESS                   | 0x10    | 1    | R/W- access      |
| BU_BM_CTL0                     | 0x11    | 2    | R/W              |
| BU_BM_TARGET_IX                | 0x12    | 4    | R/W              |
| BU_BM_PRES_NUM                 | 0x13    | 8    | R/W-asynchronous |
| BU_BM_THIS_PNUM                | 0x14    | 8    | R/W              |
| BU_BM_PIC_NUM0                 | 0x15    | 8    | R/W              |
| BU_BM_PIC_NUM1                 | 0x16    | 8    | R/W              |
| BU_BM_PIC_NUM2                 | 0x17    | 8    | R/W              |
| BU_BM_TEMP_REF                 | 0x18    | 5    | RO               |

10 Table C.11.1 Top-Level Registers A Top Level Address Map

| REGISTER NAME              | Address | Bits | COMMENT                                                             |
|----------------------------|---------|------|---------------------------------------------------------------------|
| BU_ADDGEN_KEYHOLE_ADDR_MSB | 0x28    | 1    | R/W- Address generator<br>keyhole. See<br>Table C.11.2 for contents |
| BU_ADDGEN_KEYHOLE_ADDR_LSS | 0x29    | 8    |                                                                     |
| BU_ADDGEN_KEYHOLE_DATA     | 0x2a    | 8    |                                                                     |
| BU_IT_PAGE_START           | 0x30    | 5    | R/W                                                                 |
| BU_IT_READ_CYCLE           | 0x31    | 4    | R/W                                                                 |
| BU_IT_WRITE_CYCLE          | 0x32    | 4    | R/W                                                                 |
| BU_IT_REFRESH_CYCLE        | 0x33    | 4    | R/W                                                                 |
| BU_IT_RAS_FALLING          | 0x34    | 4    | R/W                                                                 |
| BU_IT_CAS_FALLING          | 0x35    | 4    | R/W                                                                 |
| BU_IT_CONFIG               | 0x36    | 1    | R/W                                                                 |
| BU_OC_ACCESS               | 0x40    | 1    | R/W- access                                                         |
| BU_OC_MODE                 | 0x41    | 2    | R/W                                                                 |
| BU_OC_2WIRE                | 0x42    | 1    | R/W                                                                 |
| BU_OC_BORDER_R             | 0x49    | 8    | R/W                                                                 |
| BU_OC_BORDER_G             | 0x4a    | 8    | R/W                                                                 |
| BU_OC_BORDER_B             | 0x4b    | 8    | R/W                                                                 |
| BU_OC_BLANK_R              | 0x4d    | 8    | R/W                                                                 |
| BU_OC_BLANK_G              | 0x4e    | 8    | R/W                                                                 |
| BU_OC_BLANK_B              | 0x4f    | 8    | R/W                                                                 |
| BU_OC_HDELAY_1             | 0x50    | 3    | R/W                                                                 |
| BU_OC_HDELAY_0             | 0x51    | 8    | R/W                                                                 |
| BU_OC_WEST_1               | 0x52    | 3    | R/W                                                                 |
| BU_OC_WEST_0               | 0x53    | 8    | R/W                                                                 |
| BU_OC_EAST_1               | 0x54    | 3    | R/W                                                                 |
| BU_OC_EAST_0               | 0x55    | 8    | R/W                                                                 |
| BU_OC_WIDTH_1              | 0x56    | 3    | R/W                                                                 |
| BU_OC_WIDTH_0              | 0x57    | 8    | R/W                                                                 |
| BU_OC_VDELAY_1             | 0x58    | 3    | R/W                                                                 |
| BU_OC_VDELAY_0             | 0x59    | 8    | R/W                                                                 |
| BU_OC_NORTH_1              | 0x5a    | 3    | R/W                                                                 |
| BU_OC_NORTH_0              | 0x5b    | 8    | R/W                                                                 |
| BU_OC_SOUTH_1              | 0x5c    | 3    | R/W                                                                 |
| BU_OC_SOUTH_0              | 0x5d    | 8    | R/W                                                                 |
| BU_OC_HEIGHT_1             | 0x5e    | 3    | R/W                                                                 |
| BU_OC_HEIGHT_0             | 0x5f    | 8    | R/W                                                                 |

Table C.11.1 Top-Level Registers A Top  
Level Address Map (contd)

| REGISTER NAME                                    | Address | Bits | COMMENT                                 |
|--------------------------------------------------|---------|------|-----------------------------------------|
| BU_IF_CONFIGURE                                  | 0x60    | 5    | R/W                                     |
| BU_UV_MODE                                       | 0x61    | 6    | R/W - xxxxxxxx                          |
| BU_COEFF_KEYADDR                                 | 0x62    | 7    | R/W - See Table C.11.3<br>for contents. |
| BU_COEFF_KEYDATA                                 | 0x63    | 8    |                                         |
| BU_GA_ACCESS                                     | 0x68    | 1    | R/W                                     |
| BU_GA_BYPASS                                     | 0x69    | 1    | R/W                                     |
| BU_GA_RAM0_ADDR                                  | 0x6a    | 8    | R/W                                     |
| BU_GA_RAM0_DATA                                  | 0x6b    | 8    | R/W                                     |
| BU_GA_RAM1_ADDR                                  | 0x6c    | 8    | R/W                                     |
| BU_GA_RAM1_DATA                                  | 0x6d    | 8    | R/W                                     |
| BU_GA_RAM2_ADDR                                  | 0x6e    | 8    | R/W                                     |
| BU_GA_RAM2_DATA                                  | 0x6f    | 8    | R/W                                     |
| BU_DIVA_3                                        | 0x70    | 1    | R/W                                     |
| BU_DIVA_2                                        | 0x71    | 8    | R/W                                     |
| BU_DIVA_1                                        | 0x72    | 8    | R/W                                     |
| BU_DIVA_0                                        | 0x73    | 8    | R/W                                     |
| BU_DIVP_3                                        | 0x74    | 1    | R/W                                     |
| BU_DIVP_2                                        | 0x75    | 8    | R/W                                     |
| BU_DIVP_1                                        | 0x76    | 8    | R/W                                     |
| BU_DIVP_0                                        | 0x77    | 8    | R/W                                     |
| BU_PAD_CONFIG_1                                  | 0x78    | 7    | R/W                                     |
| BU_PAD_CONFIG_0                                  | 0x79    | 8    | R/W                                     |
| BU_PLL_RESISTORS                                 | 0x7a    | 8    | R/W                                     |
| BU_REF_INTERVAL                                  | 0x7b    | 8    | R/W                                     |
| BU_REVISION                                      | 0x7f    | 8    | RO- revision                            |
| The following registers are in the "test space". |         |      |                                         |
| They are unlikely to appear on the datasheet.    |         |      |                                         |
| BU_BM_PRES_FLAG                                  | 0x80    | 1    | R/W                                     |
| BU_BM_EXP_TR                                     | 0x81    | ..   | These registers are<br>missing on revA  |
| BU_BM_TR_DELTA                                   | 0x82    | ..   |                                         |
| BU_BM_ARR_IX                                     | 0x83    | 2    | R/W                                     |
| BU_BM_DSP_IX                                     | 0x84    | 2    | R/W                                     |
| BU_BM_RDY_IX                                     | 0x85    | 2    | R/W                                     |
| BU_BM_BSTATE3                                    | 0x86    | 2    | R/W                                     |
| BU_BM_BSTATE2                                    | 0x87    | 2    | R/W                                     |

Table C.11.1 Top-Level Registers A Top Level  
Address Map (contd)



| REGISTER NAME      | Address | Bits | COMMENT                                                                                      |
|--------------------|---------|------|----------------------------------------------------------------------------------------------|
| BU_BM_BSTATE1      | 0x88    | 2    | R/W                                                                                          |
| BU_BM_INDEX        | 0x89    | 2    | R/W                                                                                          |
| BU_BM_STATE        | 0x8a    | 5    | R/W                                                                                          |
| BU_BM_FFROMPS      | 0x8b    | 1    | R/W                                                                                          |
| BU_BM_FFROMFL      | 0x8c    | 1    | R/W                                                                                          |
| BU_DA_COMP0_SNP3   | 0x90    | 8    | R/W - These are the three<br>snoopers on the display<br>address generators<br>address output |
| BU_DA_COMP0_SNP2   | 0x91    | 8    |                                                                                              |
| BU_DA_COMP0_SNP1   | 0x92    | 8    |                                                                                              |
| BU_DA_COMP0_SNP0   | 0x93    | 8    |                                                                                              |
| BU_DA_COMP1_SNP3   | 0x94    | 8    |                                                                                              |
| BU_DA_COMP1_SNP2   | 0x95    | 8    |                                                                                              |
| BU_DA_COMP1_SNP1   | 0x96    | 8    |                                                                                              |
| BU_DA_COMP1_SNP0   | 0x97    | 8    |                                                                                              |
| BU_DA_COMP2_SNP3   | 0x98    | 8    |                                                                                              |
| BU_DA_COMP2_SNP2   | 0x99    | 8    |                                                                                              |
| BU_DA_COMP2_SNP1   | 0x9a    | 8    |                                                                                              |
| BU_DA_COMP2_SNP0   | 0x9b    | 8    |                                                                                              |
| BU_UV_RAM1A_ADDR_1 | 0xa0    | 8    | R/W - upi test access into<br>the vertical cosamplers'<br>RAMs                               |
| BU_UV_RAM1A_ADDR_0 | 0xa1    | 8    |                                                                                              |
| BU_UV_RAM1A_DATA   | 0xa2    | 8    |                                                                                              |
| BU_UV_RAM1B_ADDR_1 | 0xa4    | 8    |                                                                                              |
| BU_UV_RAM1B_ADDR_0 | 0xa5    | 8    |                                                                                              |
| BU_UV_RAM1B_DATA   | 0xa6    | 8    |                                                                                              |
| BU_UV_RAM2A_ADDR_1 | 0xa8    | 8    |                                                                                              |
| BU_UV_RAM2A_ADDR_0 | 0xa9    | 8    |                                                                                              |
| BU_UV_RAM2A_DATA   | 0xaa    | 8    |                                                                                              |
| BU_UV_RAM2B_ADDR_1 | 0xac    | 8    |                                                                                              |
| BU_UV_RAM2B_ADDR_0 | 0xad    | 8    |                                                                                              |
| BU_UV_RAM2B_DATA   | 0xae    | 8    |                                                                                              |
| BU_WA_ADDR_SNP2    | 0xb0    | 8    | R/W - snoopers on the write<br>address generator address<br>o/p.                             |
| BU_WA_ADDR_SNP1    | 0xb1    | 8    |                                                                                              |
| BU_WA_ADDR_SNP0    | 0xb2    | 8    |                                                                                              |
| BU_WA_DATA_SNP1    | 0xb4    | 8    | R/W - snoopers on data<br>output of WA                                                       |
| BU_WA_DATA_SNP0    | 0xb5    | 8    |                                                                                              |

Table C.11.1 Top-Level Registers A Top  
Level Address Map (contd)



Table C.11.2 Top-Level RegistersA  
Address Generator Keyhole

| Keyhole Register Name        | Keyhole Address | Bits | Comments                           |
|------------------------------|-----------------|------|------------------------------------|
| BU_DISPADDR_BUFFER0_BASE_MSB | 0x01            | 2    | 18 bit register.<br>Must be loaded |
| BU_DISPADDR_BUFFER0_BASE_MID | 0x02            | 3    |                                    |
| BU_DISPADDR_BUFFER0_BASE_LSB | 0x03            | 3    |                                    |
| BU_DISPADDR_BUFFER1_BASE_MSB | 0x05            | 2    | Must be Loaded                     |
| BU_DISPADDR_BUFFER1_BASE_MID | 0x06            | 3    |                                    |
| BU_DISPADDR_BUFFER1_BASE_LSB | 0x07            | 3    |                                    |
| BU_DISPADDR_BUFFER2_BASE_MSB | 0x09            | 2    | Must be Loaded                     |
| BU_DISPADDR_BUFFER2_BASE_MID | 0x0a            | 3    |                                    |
| BU_DISPADDR_BUFFER2_BASE_LSB | 0x0b            | 3    |                                    |
| BU_OLDPATH_LINE0_MSB         | 0x0d            | 2    | Test only                          |
| BU_OLDPATH_LINE0_MID         | 0x0e            | 3    |                                    |
| BU_OLDPATH_LINE0_LSB         | 0x0f            | 3    |                                    |
| BU_OLDPATH_LINE1_MSB         | 0x11            | 2    | Test only                          |
| BU_OLDPATH_LINE1_MID         | 0x12            | 3    |                                    |
| BU_OLDPATH_LINE1_LSB         | 0x13            | 3    |                                    |
| BU_OLDPATH_LINE2_MSB         | 0x15            | 2    | Test only                          |
| BU_OLDPATH_LINE2_MID         | 0x16            | 3    |                                    |
| BU_OLDPATH_LINE2_LSB         | 0x17            | 3    |                                    |
| BU_OLDPATH_VBCNT0_MSB        | 0x19            | 2    | Test only                          |
| BU_OLDPATH_VBCNT0_MID        | 0x1a            | 3    |                                    |
| BU_OLDPATH_VBCNT0_LSB        | 0x1b            | 3    |                                    |
| BU_OLDPATH_VBCNT1_MSB        | 0x1d            | 2    | Test only                          |
| BU_OLDPATH_VBCNT1_MID        | 0x1e            | 3    |                                    |
| BU_OLDPATH_VBCNT1_LSB        | 0x1f            | 3    |                                    |
| BU_OLDPATH_VBCNT2_MSB        | 0x21            | 2    | Test only                          |
| BU_OLDPATH_VBCNT2_MID        | 0x22            | 3    |                                    |
| BU_OLDPATH_VBCNT2_LSB        | 0x23            | 3    |                                    |

**Table C.11.2 Top-Level RegistersA**  
**Address Generator Keyhole**

| Keyhole Register Name        | Keyhole Address | Bits | Comments |
|------------------------------|-----------------|------|----------|
| BU_DISPADDR_COMP0_OFFSET_MSB | 0x25            | 2    | Must be  |
| BU_DISPADDR_COMP0_OFFSET_MID | 0x26            | 8    | Loaded   |
| BU_DISPADDR_COMP0_OFFSET_LSB | 0x27            | 8    |          |
| BU_DISPADDR_COMP1_OFFSET_MSB | 0x29            | 2    | Must be  |
| BU_DISPADDR_COMP1_OFFSET_MID | 0x2a            | 8    | Loaded   |
| BU_DISPADDR_COMP1_OFFSET_LSB | 0x2b            | 8    |          |
| BU_DISPADDR_COMP2_OFFSET_MSB | 0x2d            | 2    | Must be  |
| BU_DISPADDR_COMP2_OFFSET_MID | 0x2e            | 8    | Loaded   |
| BU_DISPADDR_COMP2_OFFSET_LSB | 0x2f            | 8    |          |
| BU_DISPADDR_COMP0_VBS_MSB    | 0x31            | 2    | Must be  |
| BU_DISPADDR_COMP0_VBS_MID    | 0x32            | 8    | Loaded   |
| BU_DISPADDR_COMP0_VBS_LSB    | 0x33            | 8    |          |
| BU_DISPADDR_COMP1_VBS_MSB    | 0x35            | 2    | Must be  |
| BU_DISPADDR_COMP1_VBS_MID    | 0x36            | 8    | Loaded   |
| BU_DISPADDR_COMP1_VBS_LSB    | 0x37            | 8    |          |
| BU_DISPADDR_COMP2_VBS_MSB    | 0x39            | 2    | Must be  |
| BU_DISPADDR_COMP2_VBS_MID    | 0x3a            | 8    | Loaded   |
| BU_DISPADDR_COMP2_VBS_LSB    | 0x3b            | 8    |          |
| BU_ADDR_COMP0_HBS_MSB        | 0x3d            | 2    | Must be  |
| BU_ADDR_COMP0_HBS_MID        | 0x3e            | 8    | Loaded   |
| BU_ADDR_COMP0_HBS_LSB        | 0x3f            | 8    |          |
| BU_ADDR_COMP1_HBS_MSB        | 0x41            | 2    | Must be  |
| BU_ADDR_COMP1_HBS_MID        | 0x42            | 8    | Loaded   |
| BU_ADDR_COMP1_HBS_LSB        | 0x43            | 8    |          |
| BU_ADDR_COMP2_HBS_MSB        | 0x45            | 2    | Must be  |
| BU_ADDR_COMP2_HBS_MID        | 0x46            | 8    | Loaded   |
| BU_ADDR_COMP2_HBS_LSB        | 0x47            | 8    |          |
| BU_DISPADDR_COMP0_HBS_MSB    | 0x49            | 2    | Must be  |
| BU_DISPADDR_COMP0_HBS_MID    | 0x4a            | 8    | Loaded   |
| BU_DISPADDR_COMP0_HBS_LSB    | 0x4b            | 8    |          |
| BU_DISPADDR_COMP1_HBS_MSB    | 0x4d            | 2    | Must be  |
| BU_DISPADDR_COMP1_HBS_MID    | 0x4e            | 8    | Loaded   |
| BU_DISPADDR_COMP1_HBS_LSB    | 0x4f            | 8    |          |

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Table C.11.2 Top-Level RegistersA  
Address Generator Keyhole

| Keyhole Register Name        | Keyhole Address | Bits | Comments       |
|------------------------------|-----------------|------|----------------|
| BU_DISPADDR_COMP2_HBS_MSB    | 0x51            | 2    | Must be Loaded |
| BU_DISPADDR_COMP2_HBS_MID    | 0x52            | 3    |                |
| BU_DISPADDR_COMP2_HBS_LSB    | 0x53            | 3    |                |
| BU_DISPADDR_CNT_LEFT0_MSB    | 0x55            | 2    | Test only      |
| BU_DISPADDR_CNT_LEFT0_MID    | 0x56            | 3    |                |
| BU_DISPADDR_CNT_LEFT0_LSB    | 0x57            | 3    |                |
| BU_DISPADDR_CNT_LEFT1_MSB    | 0x59            | 2    | Test only      |
| BU_DISPADDR_CNT_LEFT1_MID    | 0x5a            | 3    |                |
| BU_DISPADDR_CNT_LEFT1_LSB    | 0x5b            | 3    |                |
| BU_DISPADDR_CNT_LEFT2_MSB    | 0x5d            | 2    | Test only      |
| BU_DISPADDR_CNT_LEFT2_MID    | 0x5e            | 3    |                |
| BU_DISPADDR_CNT_LEFT2_LSB    | 0x5f            | 3    |                |
| BU_DISPADDR_PAGE_ADDR0_MSB   | 0x61            | 2    | Test only      |
| BU_DISPADDR_PAGE_ADDR0_MID   | 0x62            | 3    |                |
| BU_DISPADDR_PAGE_ADDR0_LSB   | 0x63            | 3    |                |
| BU_DISPADDR_PAGE_ADDR1_MSB   | 0x65            | 2    | Test only      |
| BU_DISPADDR_PAGE_ADDR1_MID   | 0x66            | 3    |                |
| BU_DISPADDR_PAGE_ADDR1_LSB   | 0x67            | 3    |                |
| BU_DISPADDR_PAGE_ADDR2_MSB   | 0x69            | 2    | Test only      |
| BU_DISPADDR_PAGE_ADDR2_MID   | 0x6a            | 3    |                |
| BU_DISPADDR_PAGE_ADDR2_LSB   | 0x6b            | 3    |                |
| BU_DISPADDR_BLOCK_ADDR0_MSB  | 0x6d            | 2    | Test only      |
| BU_DISPADDR_BLOCK_ADDR0_MID  | 0x6e            | 3    |                |
| BU_DISPADDR_BLOCK_ADDR0_LSB  | 0x6f            | 3    |                |
| BU_DISPADDR_BLOCK_ADDR1_MSB  | 0x71            | 2    | Test only      |
| BU_DISPADDR_BLOCK_ADDR1_MID  | 0x72            | 3    |                |
| BU_DISPADDR_BLOCK_ADDR1_LSB  | 0x73            | 3    |                |
| BU_DISPADDR_BLOCK_ADDR2_MSB  | 0x75            | 2    | Test only      |
| BU_DISPADDR_BLOCK_ADDR2_MID  | 0x76            | 3    |                |
| BU_DISPADDR_BLOCK_ADDR2_LSB  | 0x77            | 3    |                |
| BU_DISPADDR_BLOCKS_LEFT0_MSB | 0x79            | 2    | Test only      |
| BU_DISPADDR_BLOCKS_LEFT0_MID | 0x7a            | 3    |                |
| BU_DISPADDR_BLOCKS_LEFT0_LSB | 0x7b            | 3    |                |

**Table C.11.2 Top-Level RegistersA**  
**Address Generator Keyhole**

| Keyhole Register Name        | Keyhole Address | Bits | Comments       |
|------------------------------|-----------------|------|----------------|
| BU_DISPADDR_BLOCKS_LEFT1_MSB | 0x7d            | 2    | Test only      |
| BU_DISPADDR_BLOCKS_LEFT1_MID | 0x7e            | 8    |                |
| BU_DISPADDR_BLOCKS_LEFT1_LSB | 0x7f            | 8    |                |
| BU_DISPADDR_BLOCKS_LEFT2_MSB | 0x81            | 2    | Test only      |
| BU_DISPADDR_BLOCKS_LEFT2_MID | 0x82            | 8    |                |
| BU_DISPADDR_BLOCKS_LEFT2_LSB | 0x83            | 8    |                |
| BU_WADDR_BUFFER0_BASE_MSB    | 0x85            | 2    | Must be Loaded |
| BU_WADDR_BUFFER0_BASE_MID    | 0x86            | 8    |                |
| BU_WADDR_BUFFER0_BASE_LSB    | 0x87            | 8    |                |
| BU_WADDR_BUFFER1_BASE_MSB    | 0x89            | 2    | Must be Loaded |
| BU_WADDR_BUFFER1_BASE_MID    | 0x8a            | 8    |                |
| BU_WADDR_BUFFER1_BASE_LSB    | 0x8b            | 8    |                |
| BU_WADDR_BUFFER2_BASE_MSB    | 0x8d            | 2    | Must be Loaded |
| BU_WADDR_BUFFER2_BASE_MID    | 0x8e            | 8    |                |
| BU_WADDR_BUFFER2_BASE_LSB    | 0x8f            | 8    |                |
| BU_WADDR_COMP0_HMBADDR_MSB   | 0x91            | 2    | Test only      |
| BU_WADDR_COMP0_HMBADDR_MID   | 0x92            | 8    |                |
| BU_WADDR_COMP0_HMBADDR_LSB   | 0x93            | 8    |                |
| BU_WADDR_COMP1_HMBADDR_MSB   | 0x95            | 2    | Test only      |
| BU_WADDR_COMP1_HMBADDR_MID   | 0x96            | 8    |                |
| BU_WADDR_COMP1_HMBADDR_LSB   | 0x97            | 8    |                |
| BU_WADDR_COMP2_HMBADDR_MSB   | 0x99            | 2    | Test only      |
| BU_WADDR_COMP2_HMBADDR_MID   | 0x9a            | 8    |                |
| BU_WADDR_COMP2_HMBADDR_LSB   | 0x9b            | 8    |                |
| BU_WADDR_COMP0_VMBADDR_MSB   | 0x9d            | 2    | Test only      |
| BU_WADDR_COMP0_VMBADDR_MID   | 0x9e            | 8    |                |
| BU_WADDR_COMP0_VMBADDR_LSB   | 0x9f            | 8    |                |
| BU_WADDR_COMP1_VMBADDR_MSB   | 0xa1            | 2    | Test only      |
| BU_WADDR_COMP1_VMBADDR_MID   | 0xa2            | 8    |                |
| BU_WADDR_COMP1_VMBADDR_LSB   | 0xa3            | 8    |                |
| BU_WADDR_COMP2_VMBADDR_MSB   | 0xa5            | 2    | Test only      |
| BU_WADDR_COMP2_VMBADDR_MID   | 0xa6            | 8    |                |
| BU_WADDR_COMP2_VMBADDR_LSB   | 0xa7            | 8    |                |

Table C.11.2 Top-Level RegistersA  
Address Generator Keyhole

| Keyhole Register Name                   | Keyhole Address | Bits | Comments       |
|-----------------------------------------|-----------------|------|----------------|
| BU_WADDR_VBADDR_MSB                     | 0xa9            | 2    | Test only      |
| BU_WADDR_VBADDR_MID                     | 0xaa            | 8    |                |
| BU_WADDR_VBADDR_LSB                     | 0xab            | 8    |                |
| BU_WADDR_COMP0_HALF_WIDTH_IN_BLOCKS_MSB | 0xad            | 2    | Must be Loaded |
| BU_WADDR_COMP0_HALF_WIDTH_IN_BLOCKS_MID | 0xae            | 8    |                |
| BU_WADDR_COMP0_HALF_WIDTH_IN_BLOCKS_LSB | 0xaf            | 8    |                |
| BU_WADDR_COMP1_HALF_WIDTH_IN_BLOCKS_MSB | 0xb1            | 2    | Must be Loaded |
| BU_WADDR_COMP1_HALF_WIDTH_IN_BLOCKS_MID | 0xb2            | 8    |                |
| BU_WADDR_COMP1_HALF_WIDTH_IN_BLOCKS_LSB | 0xb3            | 8    |                |
| BU_WADDR_COMP2_HALF_WIDTH_IN_BLOCKS_MSB | 0xb5            | 2    | Must be Loaded |
| BU_WADDR_COMP2_HALF_WIDTH_IN_BLOCKS_MID | 0xb6            | 8    |                |
| BU_WADDR_COMP2_HALF_WIDTH_IN_BLOCKS_LSB | 0xb7            | 8    |                |
| BU_WADDR_HB_MSB                         | 0xb9            | 2    | Test only      |
| BU_WADDR_HB_MID                         | 0xba            | 8    |                |
| BU_WADDR_HB_LSB                         | 0xbb            | 8    |                |
| BU_WADDR_COMP0_OFFSET_MSB               | 0xbd            | 2    | Must be Loaded |
| BU_WADDR_COMP0_OFFSET_MID               | 0xbe            | 8    |                |
| BU_WADDR_COMP0_OFFSET_LSB               | 0xbf            | 8    |                |
| BU_WADDR_COMP1_OFFSET_MSB               | 0xc1            | 2    | Must be Loaded |
| BU_WADDR_COMP1_OFFSET_MID               | 0xc2            | 8    |                |
| BU_WADDR_COMP1_OFFSET_LSB               | 0xc3            | 8    |                |
| BU_WADDR_COMP2_OFFSET_MSB               | 0xc5            | 2    | Must be Loaded |
| BU_WADDR_COMP2_OFFSET_MID               | 0xc6            | 8    |                |
| BU_WADDR_COMP2_OFFSET_LSB               | 0xc7            | 8    |                |
| BU_WADDR_SCRATCH_MSB                    | 0xc9            | 2    | Test only      |
| BU_WADDR_SCRATCH_MID                    | 0xca            | 8    |                |
| BU_WADDR_SCRATCH_LSB                    | 0xcb            | 8    |                |
| BU_WADDR_MBS_WIDE_MSB                   | 0xcd            | 2    | Must be Loaded |
| BU_WADDR_MBS_WIDE_MID                   | 0xce            | 8    |                |
| BU_WADDR_MBS_WIDE_LSB                   | 0xcf            | 8    |                |
| BU_WADDR_MBS_HIGH_MSB                   | 0xd1            | 2    | Must be Loaded |
| BU_WADDR_MBS_HIGH_MID                   | 0xd2            | 8    |                |
| BU_WADDR_MBS_HIGH_LSB                   | 0xd3            | 8    |                |

**Table C.11.2 Top-Level RegistersA**  
**Address Generator Keyhole**

| Keyhole Register Name                  | Keyhole Address | Bits | Comments |
|----------------------------------------|-----------------|------|----------|
| BU_WADDR_COMP0_LAST_MB_IN_ROW_MSB      | 0xd5            | 2    | Must be  |
| BU_WADDR_COMP0_LAST_MB_IN_ROW_MID      | 0xd6            | 8    | Loaded   |
| BU_WADDR_COMP0_LAST_MB_IN_ROW_LSB      | 0xd7            | 8    |          |
| BU_WADDR_COMP1_LAST_MB_IN_ROW_MSB      | 0xd9            | 2    | Must be  |
| BU_WADDR_COMP1_LAST_MB_IN_ROW_MID      | 0xda            | 8    | Loaded   |
| BU_WADDR_COMP1_LAST_MB_IN_ROW_LSB      | 0xdb            | 8    |          |
| BU_WADDR_COMP2_LAST_MB_IN_ROW_MSB      | 0xdd            | 2    | Must be  |
| BU_WADDR_COMP2_LAST_MB_IN_ROW_MID      | 0xde            | 8    | Loaded   |
| BU_WADDR_COMP2_LAST_MB_IN_ROW_LSB      | 0xdf            | 8    |          |
| BU_WADDR_COMP0_LAST_MB_IN_HALF_ROW_MSB | 0xe1            | 2    | Must be  |
| BU_WADDR_COMP0_LAST_MB_IN_HALF_ROW_MID | 0xe2            | 8    | Loaded   |
| BU_WADDR_COMP0_LAST_MB_IN_HALF_ROW_LSB | 0xe3            | 8    |          |
| BU_WADDR_COMP1_LAST_MB_IN_HALF_ROW_MSB | 0xe5            | 2    | Must be  |
| BU_WADDR_COMP1_LAST_MB_IN_HALF_ROW_MID | 0xe6            | 8    | Loaded   |
| BU_WADDR_COMP1_LAST_MB_IN_HALF_ROW_LSB | 0xe7            | 8    |          |
| BU_WADDR_COMP2_LAST_MB_IN_HALF_ROW_MSB | 0xe9            | 2    | Must be  |
| BU_WADDR_COMP2_LAST_MB_IN_HALF_ROW_MID | 0xea            | 8    | Loaded   |
| BU_WADDR_COMP2_LAST_MB_IN_HALF_ROW_LSB | 0xeb            | 8    |          |
| BU_WADDR_COMP0_LAST_ROW_IN_MB_MSB      | 0xed            | 2    | Must be  |
| BU_WADDR_COMP0_LAST_ROW_IN_MB_MID      | 0xee            | 8    | Loaded   |
| BU_WADDR_COMP0_LAST_ROW_IN_MB_LSB      | 0xef            | 8    |          |
| BU_WADDR_COMP1_LAST_ROW_IN_MB_MSB      | 0xf1            | 2    | Must be  |
| BU_WADDR_COMP1_LAST_ROW_IN_MB_MID      | 0xf2            | 8    | Loaded   |
| BU_WADDR_COMP1_LAST_ROW_IN_MB_LSB      | 0xf3            | 8    |          |
| BU_WADDR_COMP2_LAST_ROW_IN_MB_MSB      | 0xf5            | 2    | Must be  |
| BU_WADDR_COMP2_LAST_ROW_IN_MB_MID      | 0xf6            | 8    | Loaded   |
| BU_WADDR_COMP2_LAST_ROW_IN_MB_LSB      | 0xf7            | 8    |          |
| BU_WADDR_COMP0_BLOCKS_PER_MB_ROW_MSB   | 0xf9            | 2    | Must be  |
| BU_WADDR_COMP0_BLOCKS_PER_MB_ROW_MID   | 0xfa            | 8    | Loaded   |
| BU_WADDR_COMP0_BLOCKS_PER_MB_ROW_LSB   | 0xfb            | 8    |          |
| BU_WADDR_COMP1_BLOCKS_PER_MB_ROW_MSB   | 0xfd            | 2    | Must be  |
| BU_WADDR_COMP1_BLOCKS_PER_MB_ROW_MID   | 0xfe            | 8    | Loaded   |
| BU_WADDR_COMP1_BLOCKS_PER_MB_ROW_LSB   | 0xff            | 8    |          |

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**Table C.11.2 Top-Level RegistersA**  
**Address Generator Keyhole**

| Keyhole Register Name                | Keyhole Address | Bits | Comments       |
|--------------------------------------|-----------------|------|----------------|
| BU_WADDR_COMP2_BLOCKS_PER_MB_ROW_MSB | 0x101           | 2    | Must be Loaded |
| BU_WADDR_COMP2_BLOCKS_PER_MB_ROW_MID | 0x102           | 8    |                |
| BU_WADDR_COMP2_BLOCKS_PER_MB_ROW_LSB | 0x103           | 8    |                |
| BU_WADDR_COMP0_LAST_MB_ROW_MSB       | 0x105           | 2    | Must be Loaded |
| BU_WADDR_COMP0_LAST_MB_ROW_MID       | 0x106           | 8    |                |
| BU_WADDR_COMP0_LAST_MB_ROW_LSB       | 0x107           | 8    |                |
| BU_WADDR_COMP1_LAST_MB_ROW_MSB       | 0x109           | 2    | Must be Loaded |
| BU_WADDR_COMP1_LAST_MB_ROW_MID       | 0x10a           | 8    |                |
| BU_WADDR_COMP1_LAST_MB_ROW_LSB       | 0x10b           | 8    |                |
| BU_WADDR_COMP2_LAST_MB_ROW_MSB       | 0x10d           | 2    | Must be Loaded |
| BU_WADDR_COMP2_LAST_MB_ROW_MID       | 0x10e           | 8    |                |
| BU_WADDR_COMP2_LAST_MB_ROW_LSB       | 0x10f           | 8    |                |
| BU_WADDR_COMP0_HBS_MSB               | 0x111           | 2    | Must be Loaded |
| BU_WADDR_COMP0_HBS_MID               | 0x112           | 8    |                |
| BU_WADDR_COMP0_HBS_LSB               | 0x113           | 8    |                |
| BU_WADDR_COMP1_HBS_MSB               | 0x115           | 2    | Must be Loaded |
| BU_WADDR_COMP1_HBS_MID               | 0x116           | 8    |                |
| BU_WADDR_COMP1_HBS_LSB               | 0x117           | 8    |                |
| BU_WADDR_COMP2_HBS_MSB               | 0x119           | 2    | Must be Loaded |
| BU_WADDR_COMP2_HBS_MID               | 0x11a           | 8    |                |
| BU_WADDR_COMP2_HBS_LSB               | 0x11b           | 8    |                |
| BU_WADDR_COMP0_MAXHB                 | 0x11f           | 2    | Must be Loaded |
| BU_WADDR_COMP1_MAXHB                 | 0x123           | 2    |                |
| BU_WADDR_COMP2_MAXHB                 | 0x127           | 2    |                |
| BU_WADDR_COMP0_MAXVB                 | 0x12b           | 2    | Must be Loaded |
| BU_WADDR_COMP1_MAXVB                 | 0x12f           | 2    |                |
| BU_WADDR_COMP2_MAXVB                 | 0x133           | 2    |                |

### C.12.3 Horizontal Upsampler and Color Space Converter Keyhole . .

Table C.11.3 H-Upsamplers and Cspace Keyhole Address Map

| Keyhole Register<br>Name | Keyhole<br>Address | Bits | Comment        |
|--------------------------|--------------------|------|----------------|
| BU_UH0_A00_1             | 0x0                | 5    | R/W- Coeff 0,0 |
| BU_UH0_A00_0             | 0x1                | 8    |                |
| BU_UH0_A01_1             | 0x2                | 5    | R/W- Coeff 0,1 |
| BU_UH0_A01_0             | 0x3                | 8    |                |
| BU_UH0_A02_1             | 0x4                | 5    | R/W- Coeff 0,2 |
| BU_UH0_A02_0             | 0x5                | 8    |                |
| BU_UH0_A03_1             | 0x6                | 5    | R/W- Coeff 0,0 |
| BU_UH0_A03_0             | 0x7                | 8    |                |
| BU_UH0_A10_1             | 0x8                | 5    | R/W- Coeff 1,0 |
| BU_UH0_A10_0             | 0x9                | 8    |                |
| BU_UH0_A11_1             | 0xa                | 5    | R/W- Coeff 1,1 |
| BU_UH0_A11_0             | 0xb                | 8    |                |
| BU_UH0_A12_1             | 0xc                | 5    | R/W- Coeff 1,2 |
| BU_UH0_A12_0             | 0xd                | 8    |                |
| BU_UH0_A13_1             | 0xe                | 5    | R/W- Coeff 1,3 |
| BU_UH0_A13_0             | 0xf                | 8    |                |
| BU_UH0_A20_1             | 0x10               | 5    | R/W- Coeff 2,0 |
| BU_UH0_A20_0             | 0x11               | 8    |                |
| BU_UH0_A21_1             | 0x12               | 5    | R/W- Coeff 2,1 |
| BU_UH0_A21_0             | 0x13               | 8    |                |
| BU_UH0_A22_1             | 0x14               | 5    | R/W- Coeff 2,2 |
| BU_UH0_A22_0             | 0x15               | 8    |                |
| BU_UH0_A23_1             | 0x16               | 5    | R/W- Coeff 2,3 |
| BU_UH0_A23_0             | 0x17               | 8    |                |
| BU_UH0_MODE              | 0x18               | 2    | R/W            |
| BU_UH1_A00_1             | 0x20               | 5    | R/W- Coeff 0,0 |
| BU_UH1_A00_0             | 0x21               | 8    |                |
| BU_UH1_A01_1             | 0x22               | 5    | R/W- Coeff 0,1 |
| BU_UH1_A01_0             | 0x23               | 8    |                |
| BU_UH1_A02_1             | 0x24               | 5    | R/W- Coeff 0,2 |
| BU_UH1_A02_0             | 0x25               | 8    |                |
| BU_UH1_A03_1             | 0x26               | 5    | R/W- Coeff 0,0 |
| BU_UH1_A03_0             | 0x27               | 8    |                |

Table C.11.3 H-Upsamplers and Cspace Keyhole Address Map

| Keyhole Register Name | Keyhole Address | Bits | Comment        |
|-----------------------|-----------------|------|----------------|
| BU_UH1_A10_1          | 0x28            | 5    | R/W- Coeff 1.0 |
| BU_UH1_A10_0          | 0x29            | 8    |                |
| BU_UH1_A11_1          | 0x2a            | 5    | R/W- Coeff 1.1 |
| BU_UH1_A11_0          | 0x2b            | 8    |                |
| BU_UH1_A12_1          | 0x2c            | 5    | R/W- Coeff 1.2 |
| BU_UH1_A12_0          | 0x2d            | 8    |                |
| BU_UH1_A13_1          | 0x2e            | 5    | R/W- Coeff 1.3 |
| BU_UH1_A13_0          | 0x2f            | 8    |                |
| BU_UH1_A20_1          | 0x30            | 5    | R/W- Coeff 2.0 |
| BU_UH1_A20_0          | 0x31            | 8    |                |
| BU_UH1_A21_1          | 0x32            | 5    | R/W- Coeff 2.1 |
| BU_UH1_A21_0          | 0x33            | 8    |                |
| BU_UH1_A22_1          | 0x34            | 5    | R/W- Coeff 2.2 |
| BU_UH1_A22_0          | 0x35            | 8    |                |
| BU_UH1_A23_1          | 0x36            | 5    | R/W- Coeff 2.3 |
| BU_UH1_A23_0          | 0x37            | 8    |                |
| BU_UH1_MODE           | 0x38            | 2    | R/W            |
| BU_UH2_A00_1          | 0x40            | 5    | R/W- Coeff 0.0 |
| BU_UH2_A00_0          | 0x41            | 8    |                |
| BU_UH2_A01_1          | 0x42            | 5    | R/W- Coeff 0.1 |
| BU_UH2_A01_0          | 0x43            | 8    |                |
| BU_UH2_A02_1          | 0x44            | 5    | R/W- Coeff 0.2 |
| BU_UH2_A02_0          | 0x45            | 8    |                |
| BU_UH2_A03_1          | 0x46            | 5    | R/W- Coeff 0.0 |
| BU_UH2_A03_0          | 0x47            | 8    |                |
| BU_UH2_A10_1          | 0x48            | 5    | R/W- Coeff 1.0 |
| BU_UH2_A10_0          | 0x49            | 8    |                |
| BU_UH2_A11_1          | 0x4a            | 5    | R/W- Coeff 1.1 |
| BU_UH2_A11_0          | 0x4b            | 8    |                |
| BU_UH2_A12_1          | 0x4c            | 5    | R/W- Coeff 1.2 |
| BU_UH2_A12_0          | 0x4d            | 8    |                |
| BU_UH2_A13_1          | 0x4e            | 5    | R/W- Coeff 1.3 |
| BU_UH2_A13_0          | 0x4f            | 8    |                |

00000000000000000000000000000000

Table C.11.3 H-Upsamplers and Cspace Keyhole Address Map

| Keyhole Register<br>Name | Keyhole<br>Address | Bits | Comment        |
|--------------------------|--------------------|------|----------------|
| BU_UH2_A20_1             | 0x50               | 5    | R/W- Coeff 2.0 |
| BU_UH2_A20_0             | 0x51               | 8    |                |
| BU_UH2_A21_1             | 0x52               | 5    | R/W- Coeff 2.1 |
| BU_UH2_A21_0             | 0x53               | 8    |                |
| BU_UH2_A22_1             | 0x54               | 5    | R/W- Coeff 2.2 |
| BU_UH2_A22_0             | 0x55               | 8    |                |
| BU_UH2_A23_1             | 0x56               | 5    | R/W- Coeff 2.3 |
| BU_UH2_A23_0             | 0x57               | 8    |                |
| BU_UH2_MODE              | 0x58               | 2    | R/W            |
| BU_CS_A00_1              | 0x60               | 5    | R/W            |
| BU_CS_A00_0              | 0x61               | 8    |                |
| BU_CS_A10_1              | 0x62               | 5    | R/W            |
| BU_CS_A10_0              | 0x63               | 8    |                |
| BU_CS_A20_1              | 0x64               | 5    | R/W            |
| BU_CS_A20_0              | 0x65               | 8    |                |
| BU_CS_B0_1               | 0x66               | 6    | R/W            |
| BU_CS_B0_0               | 0x67               | 8    |                |
| BU_CS_A01_1              | 0x68               | 5    | R/W            |
| BU_CS_A01_0              | 0x69               | 8    |                |
| BU_CS_A11_1              | 0x6a               | 5    | R/W            |
| BU_CS_A11_0              | 0x6b               | 8    |                |
| BU_CS_A21_1              | 0x6c               | 5    | R/W            |
| BU_CS_A21_0              | 0x6d               | 8    |                |
| BU_CS_B1_1               | 0x6e               | 6    | R/W            |
| BU_CS_B1_0               | 0x6f               | 8    |                |
| BU_CS_A02_1              | 0x70               | 5    | R/W            |
| BU_CS_A02_0              | 0x71               | 8    |                |
| BU_CS_A12_1              | 0x72               | 5    | R/W            |
| BU_CS_A12_0              | 0x73               | 8    |                |
| BU_CS_A22_1              | 0x74               | 5    | R/W            |
| BU_CS_A22_0              | 0x75               | 8    |                |
| BU_CS_B2_1               | 0x76               | 6    | R/W            |
| BU_CS_B2_0               | 0x77               | 8    |                |

There are five picture size events, and the primary response of each is given below:

In addition, the following calculations are necessary to retain consistent picture size parameters:

```

if (hmbbs_event||vmbbs_event||
    def_samp0_event||def_samp1_event||def_samp2_event)
{
    for (i=0; i<max_component; i++)
    {
        hbs[i] = addh_hbs[i] = (maxhb[i]+1) * mbs_wide;
        half_width_in_blocks[i] = ((maxhb[i]+1) * mbs_wide)/2;
        last_mb_in_row[i] = hbs[i] - (maxhb[i]-1);
        last_mb_in_half_row[i] = half_width_in_blocks[i] -
            (maxhb[i]-1);
        last_row_in_mb[i] = hbs[i] * maxvb[i];
        blocks_per_mb_row[i] = last_row_in_mb[i] - hbs[i];
        last_mb_row[i] = blocks_per_mb_row[i] * (mbs_high-1);
    }
}

```

Although it is not strictly necessary to modify the dispaddr register values (such as the display window size) in response to picture size interrupts, this may be desirable depending on the application requirements.

### 5 C.13.3 Register Values for SIF Pictures

The values contained in all the picture size registers after the above interrupt processing for an SIF, 4:2:0 stream will be as follows:

#### C.13.3.1 Primary Values

```

BU_WADDR_MBS_WIDE = 0x16
BU_WADDR_MBS_HIGH = 0x12
BU_WADDR_COMP0_MAXHB = 0x01
BU_WADDR_COMP1_MAXHB = 0x00
BU_WADDR_COMP2_MAXHB = 0x00
BU_WADDR_COMP0_MAXVB = 0x01
BU_WADDR_COMP1_MAXVB = 0x00
BU_WADDR_COMP2_MAXVB = 0x00

```

### 10 C.13.3.2 Secondary Values - After Calculation

```

BU_WADDR_COMP0_HBS = 0x2C
BU_WADDR_COMP1_HBS = 0x16
BU_WADDR_COMP2_HBS = 0x16
BU_ADDR_COMP0_HBS = 0x2C
BU_ADDR_COMP1_HBS = 0x16
BU_ADDR_COMP2_HBS = 0x16
BU_WADDR_COMP0_HALF_WIDTH_IN_BLOCKS = 0x16
BU_WADDR_COMP1_HALF_WIDTH_IN_BLOCKS = 0x0B
BU_WADDR_COMP2_HALF_WIDTH_IN_BLOCKS = 0x0B
BU_WADDR_COMP0_LAST_MB_IN_ROW = 0x2A

```

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```

BU_WADDR_COMP1_LAST_MB_IN_ROW = 0x15
BU_WADDR_COMP2_LAST_MB_IN_ROW = 0x15
BU_WADDR_COMP0_LAST_MB_IN_HALF_ROW = 0x14
BU_WADDR_COMP1_LAST_MB_IN_HALF_ROW = 0x0A
BU_WADDR_COMP2_LAST_MB_IN_HALF_ROW = 0x0A
BU_WADDR_COMP0_LAST_ROW_IN_MB = 0x2C
BU_WADDR_COMP1_LAST_ROW_IN_MB = 0x0
BU_WADDR_COMP2_LAST_ROW_IN_MB = 0x0
BU_WADDR_COMP0_BLOCKS_PER_MB_ROW = 0x58
BU_WADDR_COMP1_BLOCKS_PER_MB_ROW = 0x16
BU_WADDR_COMP2_BLOCKS_PER_MB_ROW = 0x16
BU_WADDR_COMP0_LAST_MB_ROW = 0x5D8
BU_WADDR_COMP1_LAST_MB_ROW = 0x176
BU_WADDR_COMP2_LAST_MB_ROW = 0x176

```

Note that if these values are to be written explicitly at setup, account must be taken of the multi-byte nature of most of the locations.

Note that additional Figures, which are self explanatory to those of ordinary skill in the art, are included with this application for providing further insight into the detailed structure and operation of the environment in which the present invention is intended to function.



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The aforescribed pipeline system of the present invention satisfies a long existing need for an improved system having an input, an output and a plurality of processing stages between the input and the output, the plurality of processing stages being interconnected by a two-wire interface for conveyance of tokens along the pipeline, and control and/or DATA tokens in the form of universal adaptation units for interfacing with all of the processing stages in the pipeline and interacting with selected stages in the pipeline for control data and/or combined control-data functions among the processing stages, so that the processing stages in the pipeline are afforded enhanced flexibility in configuration and processing. In accordance with the invention, the processing stages may be configurable in response to recognition of at least one token. One of the processing stages may be a Start Code Detector which receives the input and generates and/or converts the tokens.

The present invention also relates to an improved pipeline system having a spatial decoder system for video data including a Huffman decoder, an index to data and an arithmetic logic unit, and a microcode ROM having separate stored programs for each of a plurality of different picture compression/decompression standards, such programs being selectable by a token, whereby processing for a plurality of different picture standards is facilitated. The present invention may also include tokens in the form of a PICTURE\_START code token for indicating that the start of a picture will follow in the subsequent DATA token, a PICTURE\_END token for indicating the end of an individual picture, a FLUSH token for clearing buffers and resetting the system, and a CODING\_STANDARD token for conditioning the system for processing in a selected one of a plurality of picture compression/decompression standards. The present invention also relates to an improved pipeline system for decoding video data and having a Huffman decoder, an index to data (ITOD) stage,

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Huffman coded data words receiving means for generating an index number associated with each JPEG Huffman coded data word received from the Huffman coded data words receiving means, means for operating a lookup table containing a Huffman code table having the format used under the JPEG standard to transmit JPEG Huffman table information, including an input for receiving an index number from the index number generating means, and including an output that is a decoded data word corresponding to the index number.

The improved system includes a multi-standard video decompression apparatus having a plurality of stages interconnected by a two-wire interface arranged as a pipeline processing machine. Control tokens and DATA Tokens pass over the single two-wire interface for carrying both control and data in token format. A token decode circuit is positioned in certain of the stages for recognizing certain of the tokens as control tokens pertinent to that stage and for passing unrecognized control tokens along the pipeline. Reconfiguration processing circuits are positioned in selected stages and are responsive to a recognized control token for reconfiguring such stage to handle an identified DATA Token. A wide variety of unique supporting subsystem circuitry and processing techniques are disclosed for implementing the system.

It will be apparent from the foregoing that, while particular forms of the invention have been illustrated and described, various modification can be made without departing from the spirit and scope of the invention. Accordingly, it is not intended that the invention be limited, except as by the appended claims.

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**ABSTRACT**

A pipeline video decoder and decompression system handles a plurality of separately encoded bit streams arranged as a single serial bit stream of digital bits and having separately encoded pairs of control codes and corresponding data carried in the serial bit stream. The pipeline system employs a plurality of interconnected stages to decode and decompress the single bit stream, including a start code detector. When in a search mode, the start code detector searches for a specific start code corresponding to one of multiple compression standards. The start code detector responding to the single serial bit stream generates control tokens and data tokens. A respective one of the tokens includes a plurality of data words. Each data word has an extension bit which indicates a presence of additional words therein. The data words are thereby unlimited in number. A token decode circuit positioned in certain of the stages recognizes certain of the tokens as control tokens pertinent to that stage and passes unrecognized control tokens to a succeeding stage. A reconfigurable decode and parser processing means positioned in certain of the stages is responsive to a recognized control token and reconfigures a particular stage to handle an identified data token. Methods relating to the decoder and decompression system include processing steps relating thereto

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:

Adrian P. Wise

Filed: HERewith

For: MULTISTANDARD VIDEO  
DECODER AND DECOMPRESSION  
SYSTEM FOR PROCESSING  
ENCODED BIT STREAMS INCLUDING  
START CODES AND METHODS  
RELATING THERETO

1. *What is the purpose of this document?*  
 2. *What are the main findings of the study?*  
 3. *What are the implications of the findings?*  
 4. *What are the limitations of the study?*  
 5. *What are the conclusions of the study?*  
 6. *What are the recommendations of the study?*  
 7. *What are the future research directions?*  
 8. *What are the acknowledgments?*  
 9. *What are the references?*  
 10. *What are the appendices?*  
 11. *What are the footnotes?*  
 12. *What are the tables?*  
 13. *What are the figures?*  
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Application No.: Not Yet Known

Art Unit: 2783 (anticipated)

Examiner: Follansbee, J. (anticipated)

## COMMUNICATION - SUBMISSION OF FORMAL DRAWINGS

Assistant Commissioner for Patents  
Washington DC 20231

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 Express Mail Number  
 Date of Deposit

Transmitted herewith are 169 formal drawings on 124 sheets.

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Respectfully submitted,

Date: October 12, 2000

DISCOVISION ASSOCIATES

**DISCOVISION ASSOCIATES**  
**INTELLECTUAL PROPERTY DEVELOPMENT**  
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RS:sd

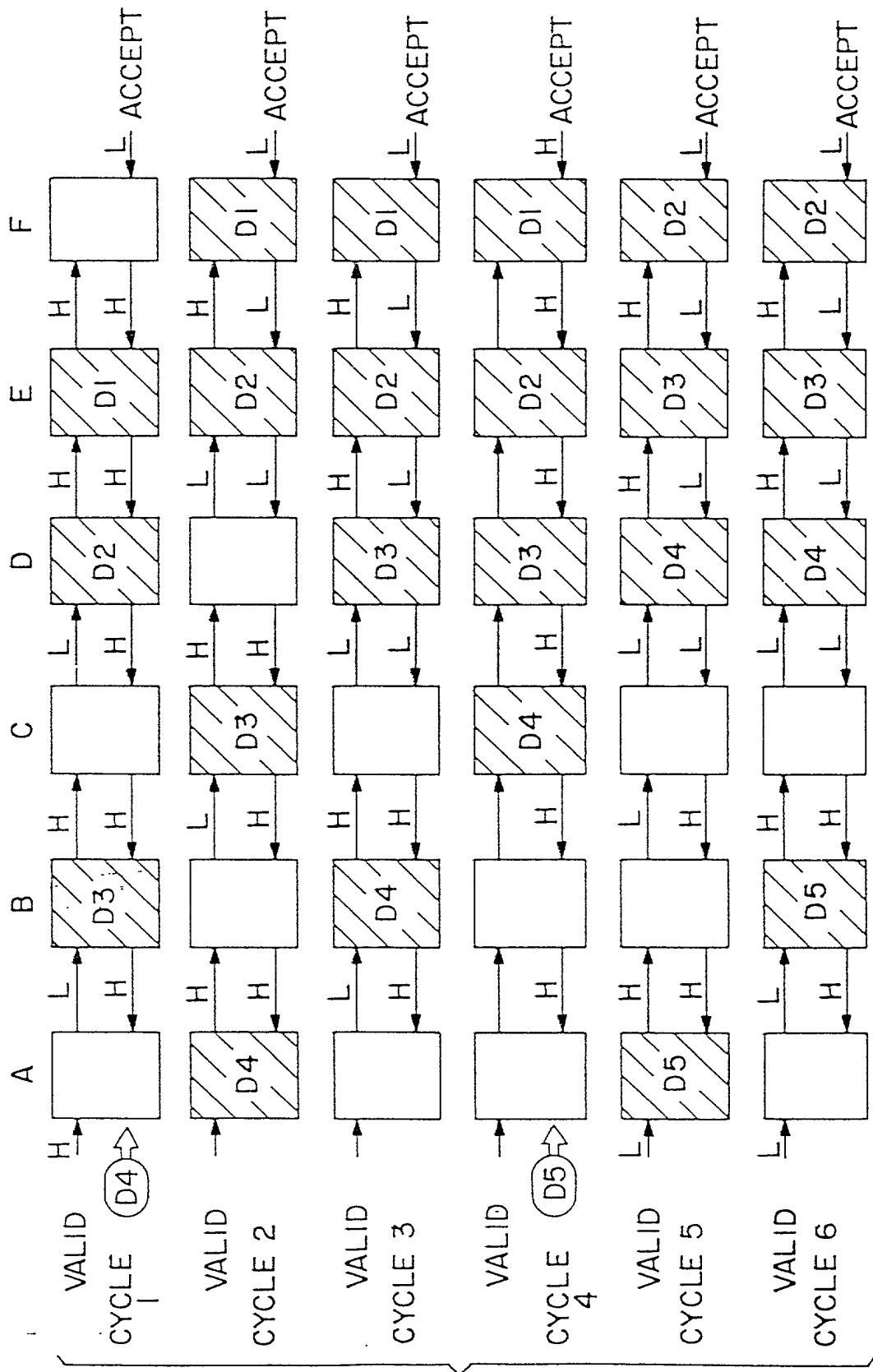


FIG. 1

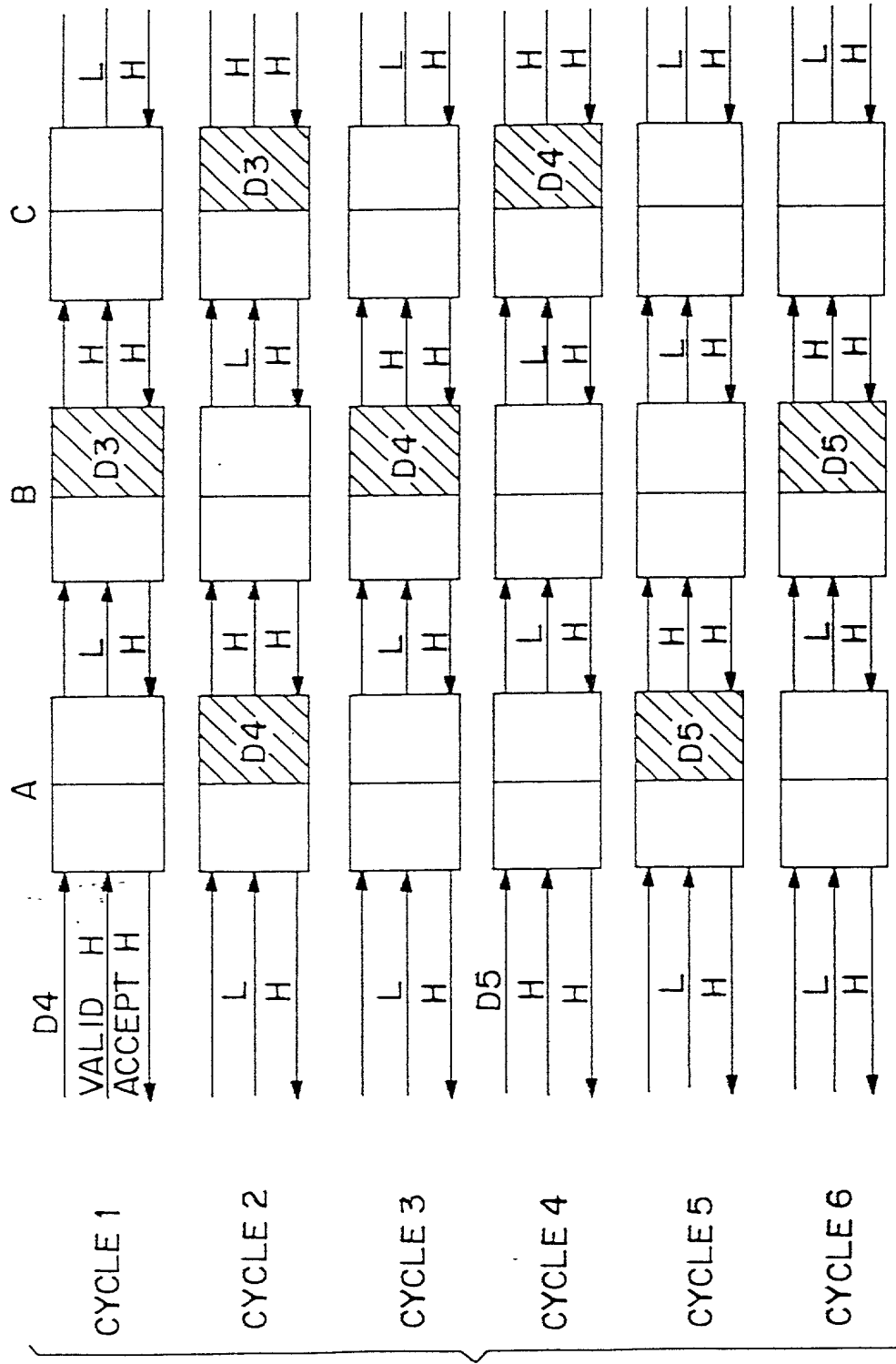


FIG.2(A)

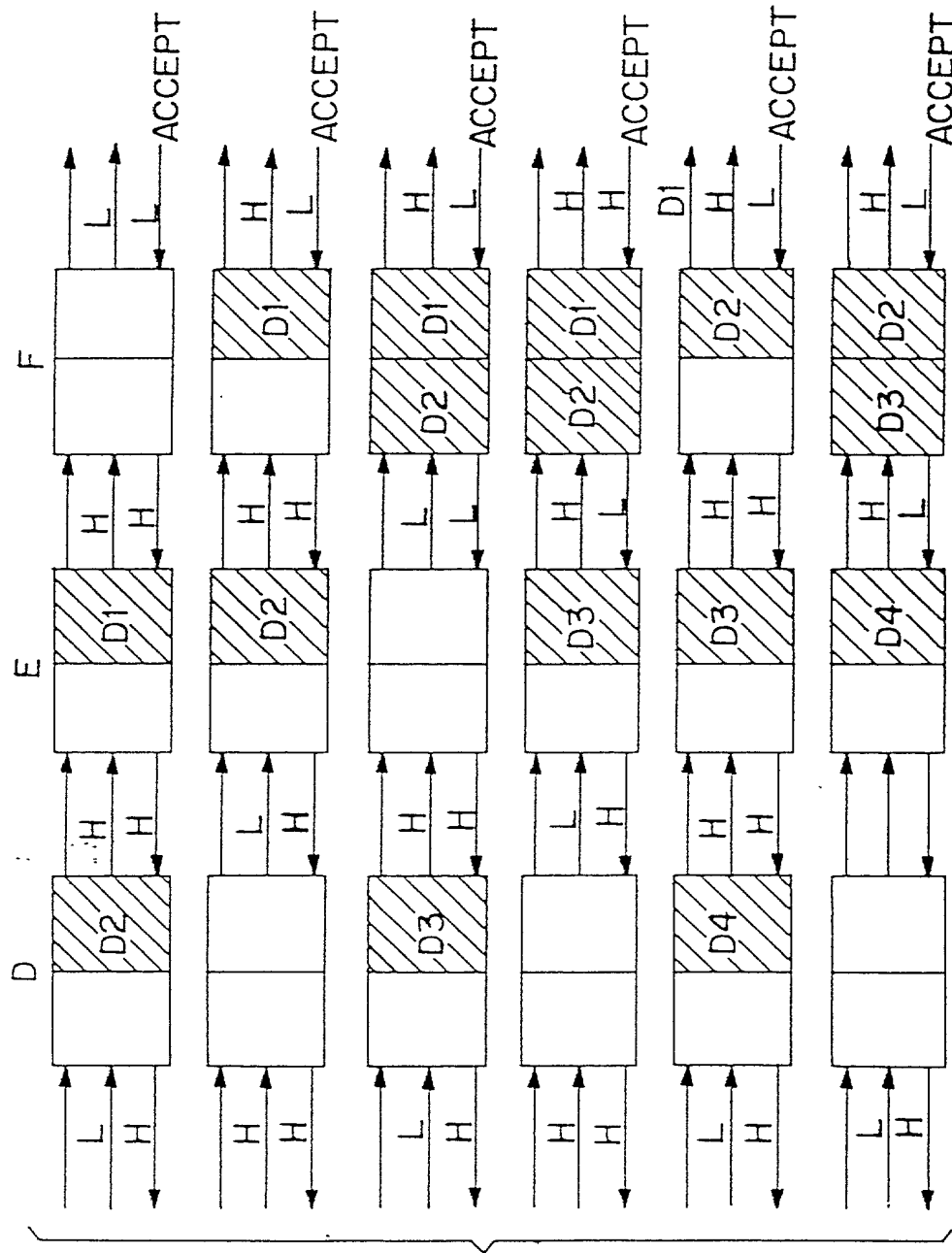
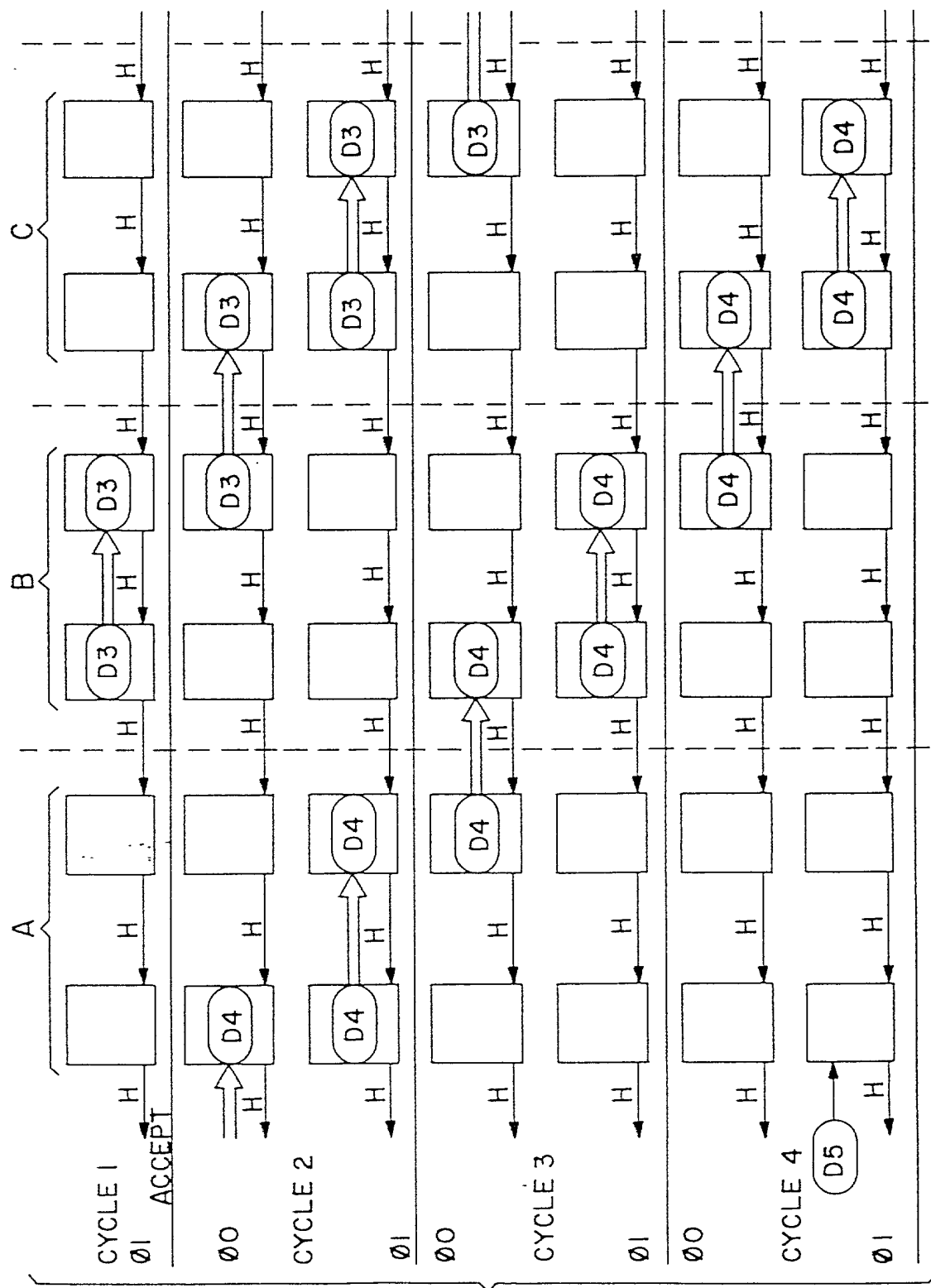


FIG. 2(B)





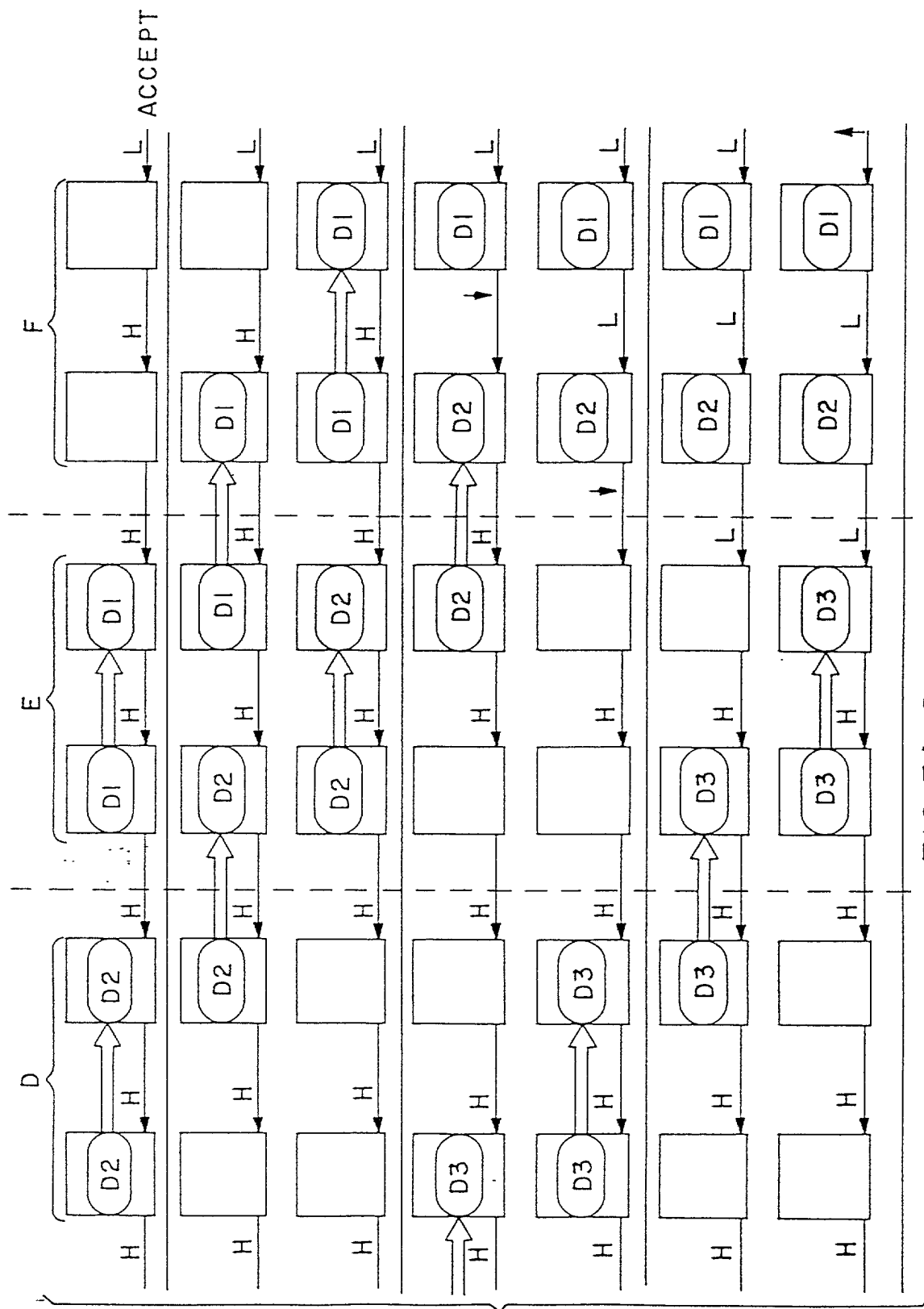


FIG. 3A-2

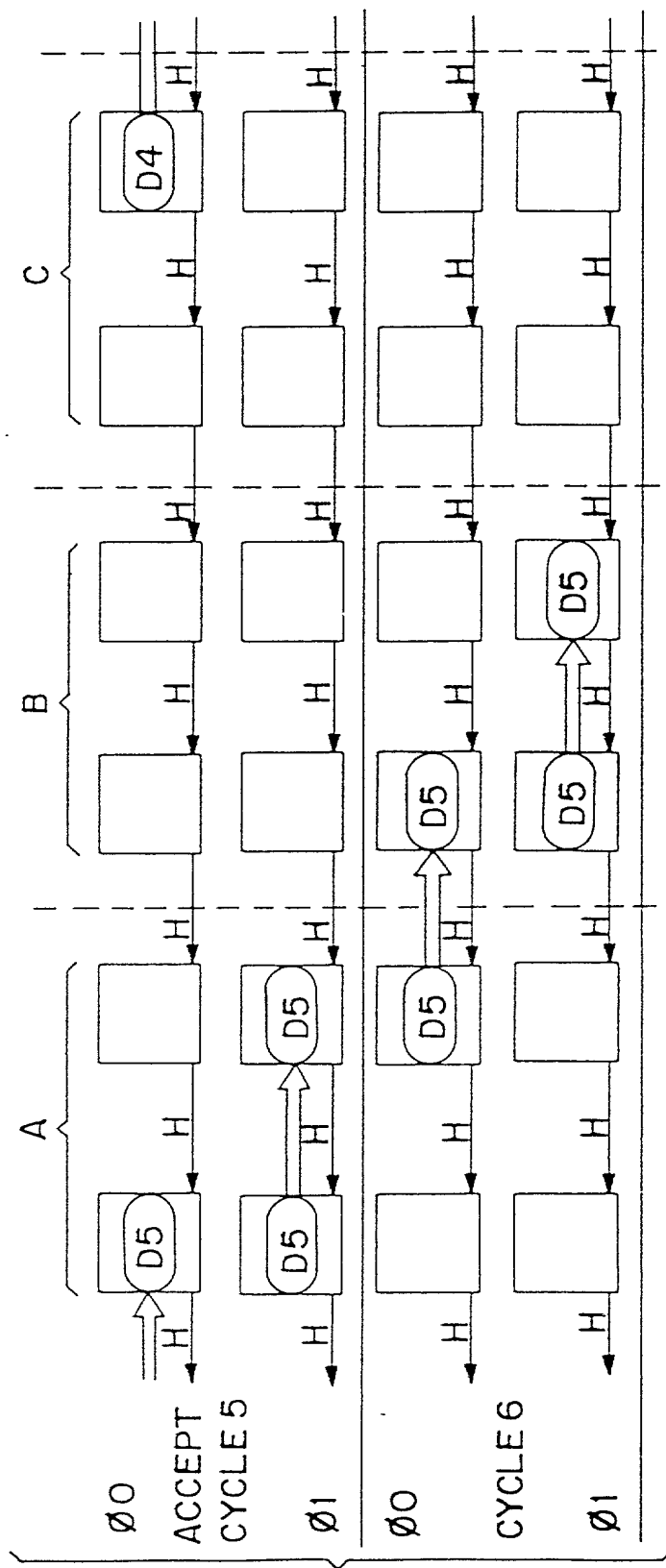


FIG. 3B-1

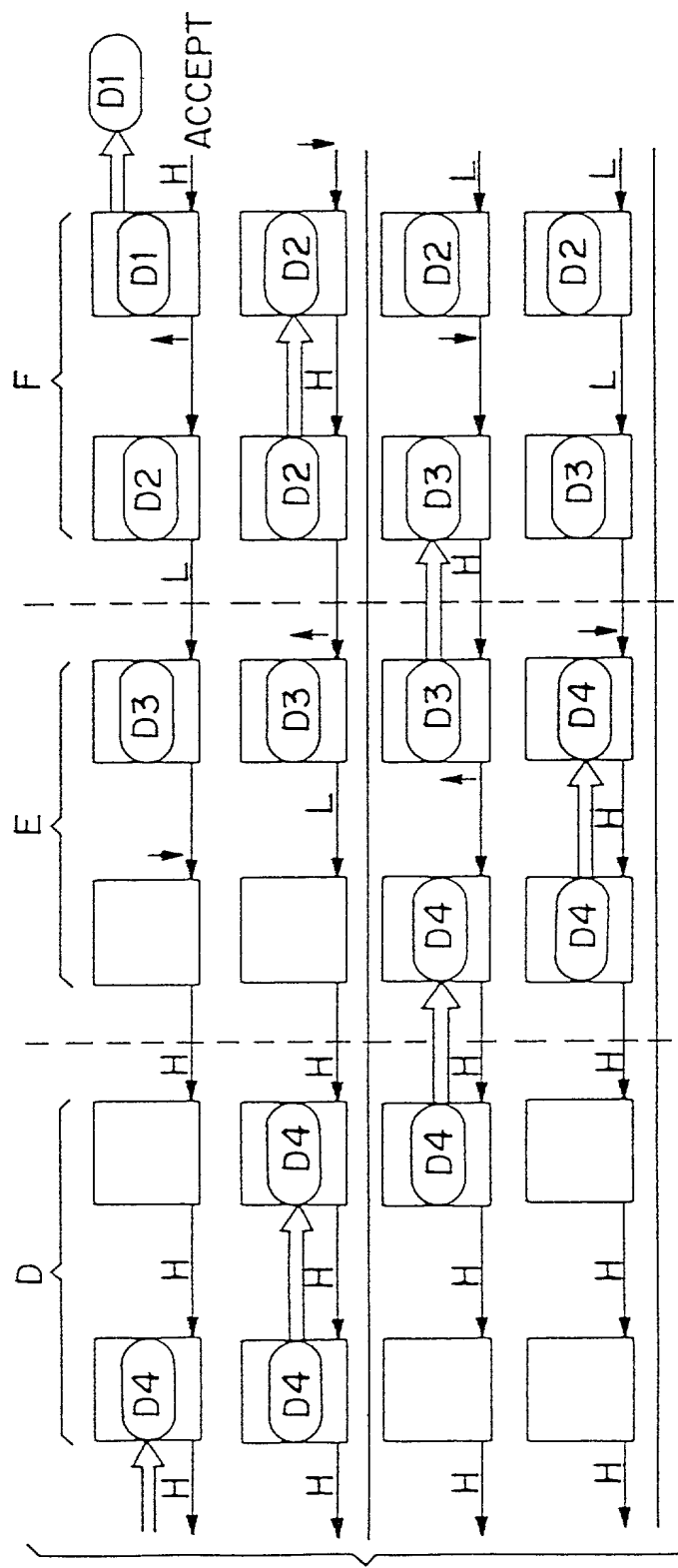


FIG. 3B-2







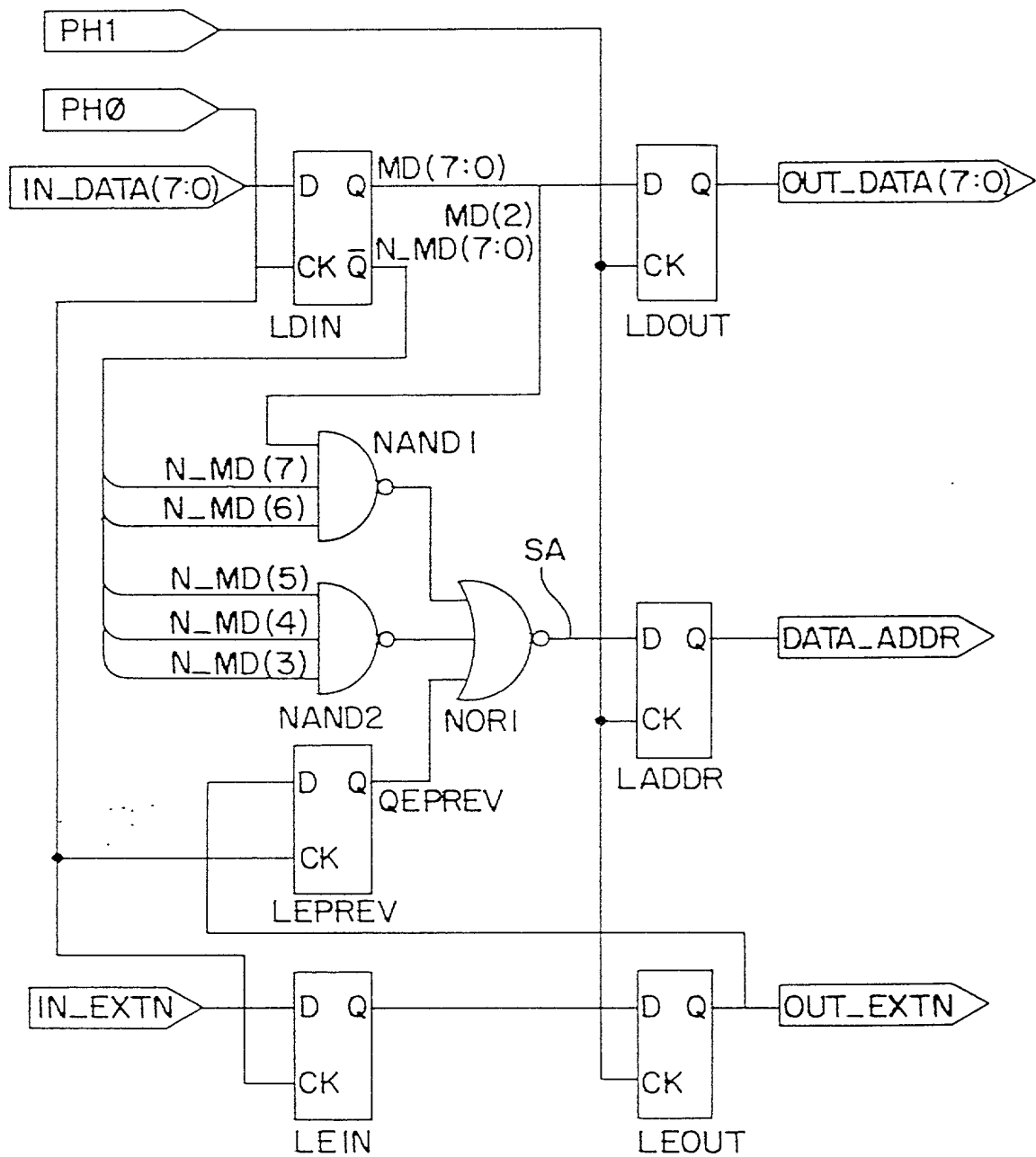


FIG. 6



FIG. 7



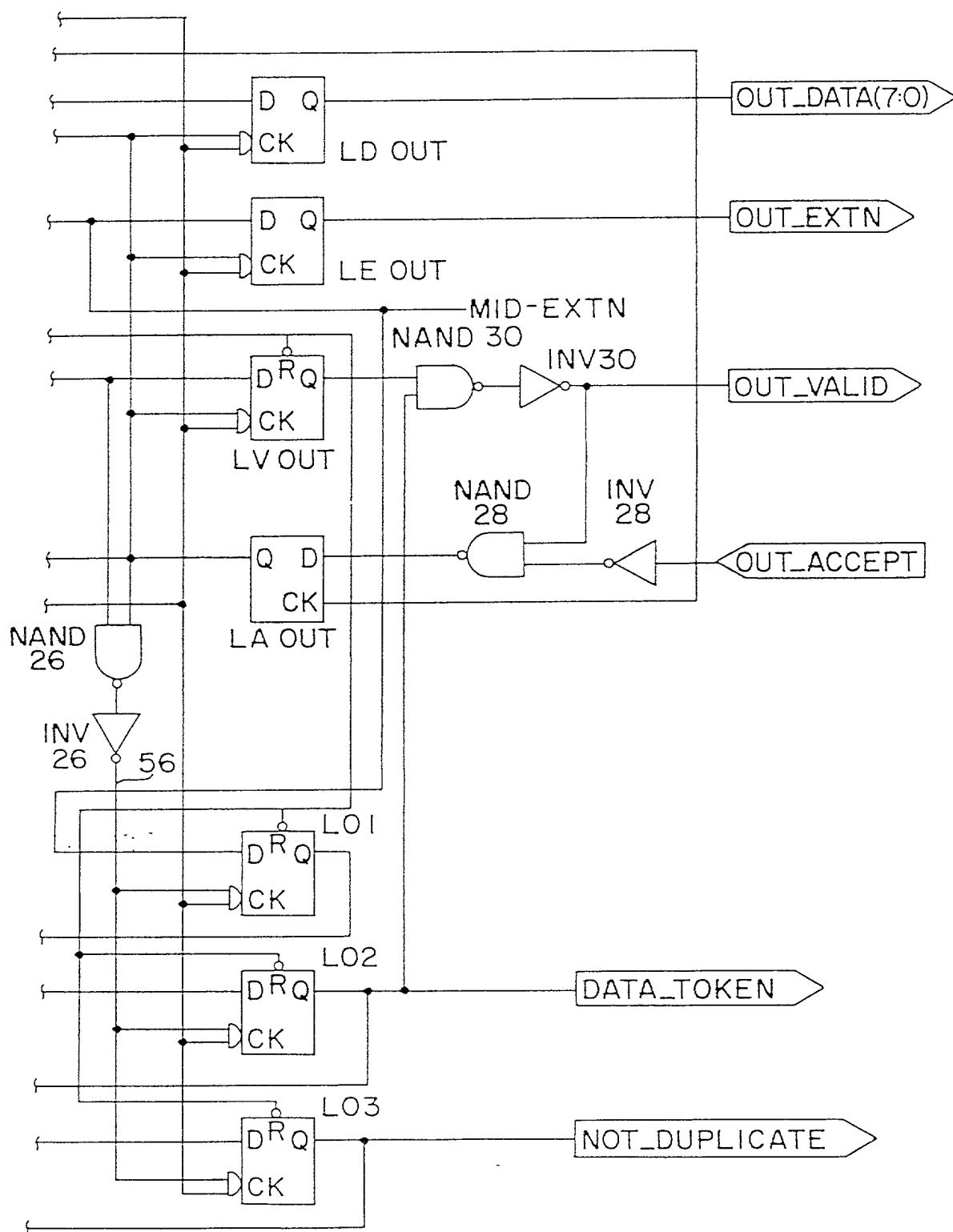


FIG. 8(B)







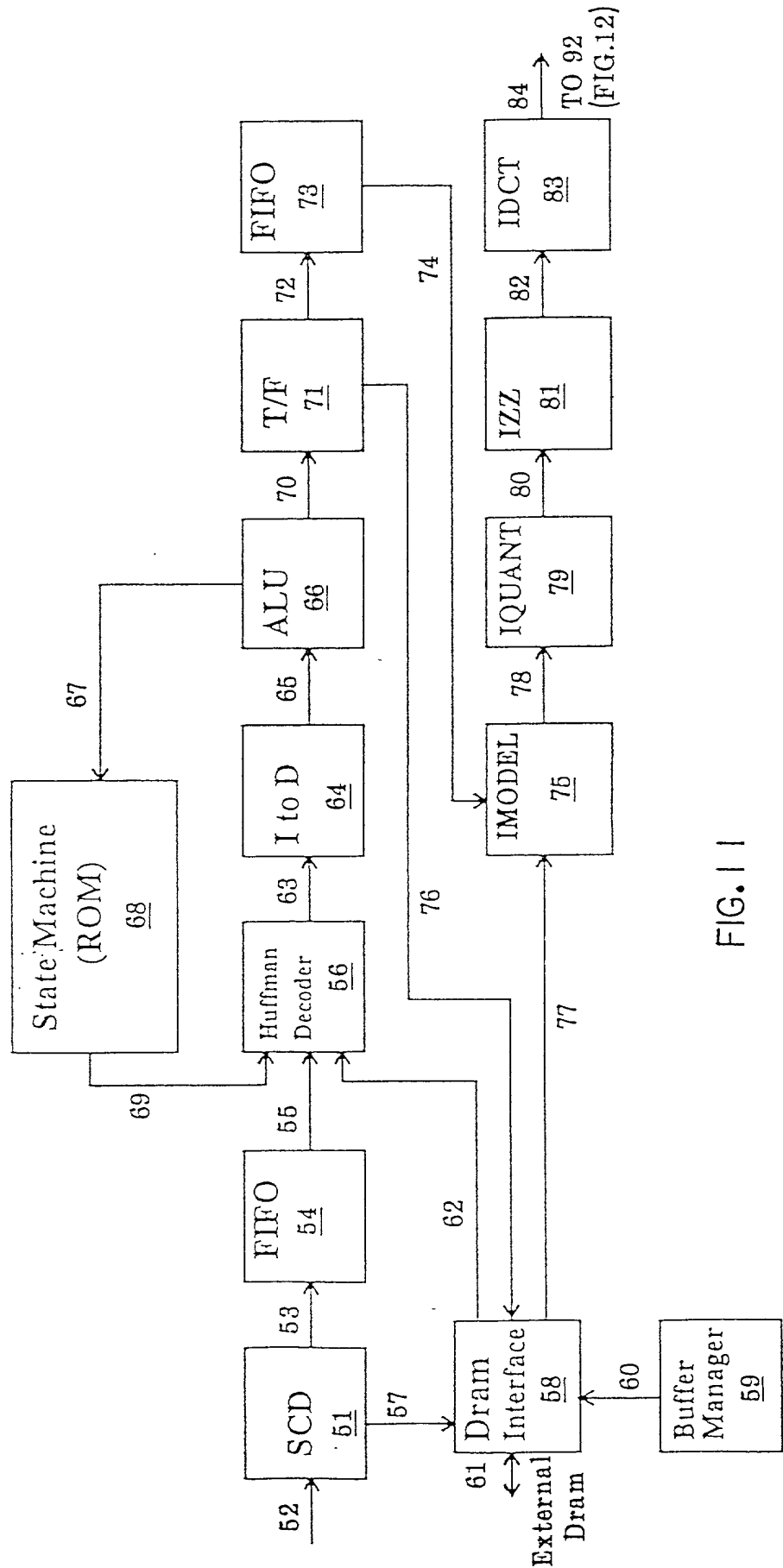


FIG. 11

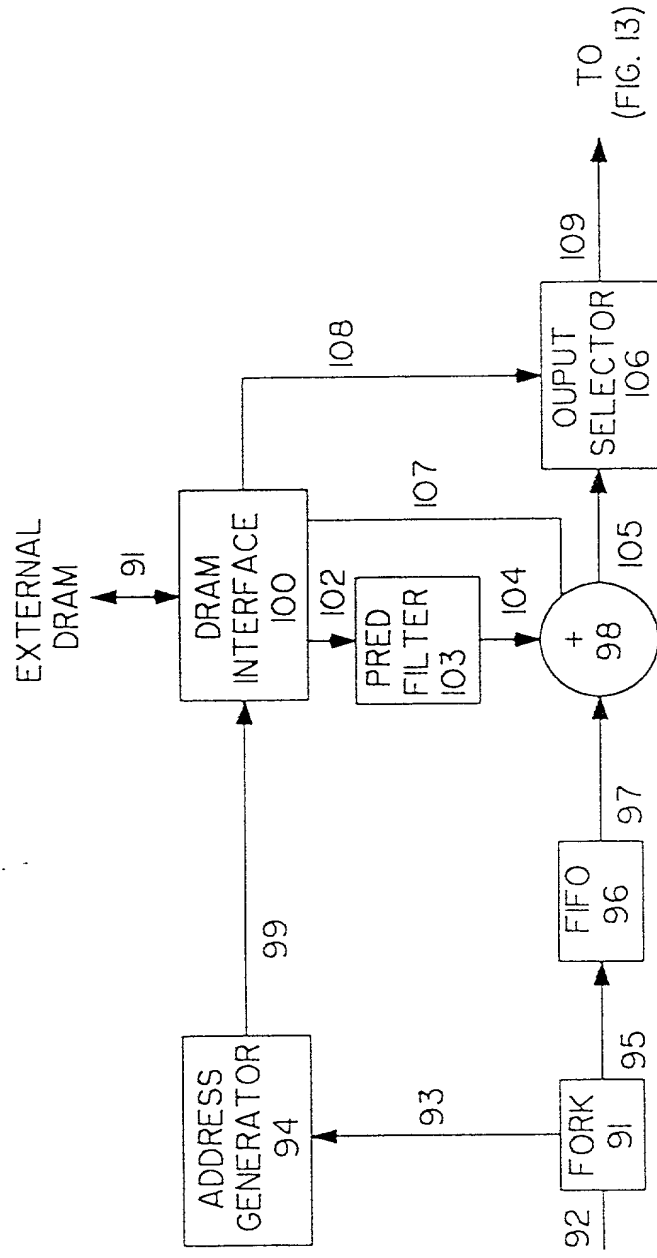


FIG. 12



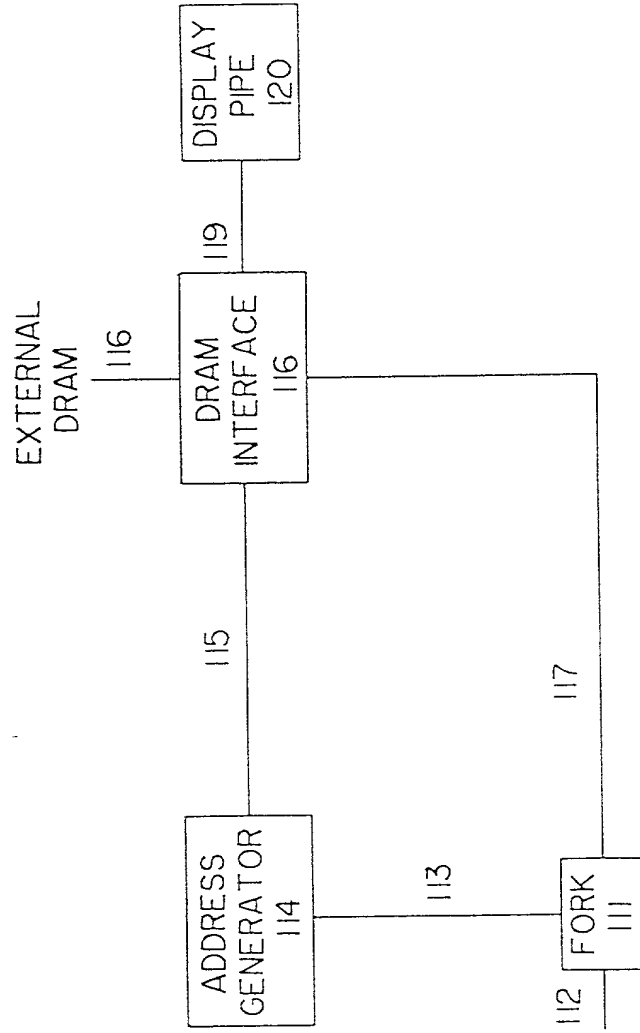
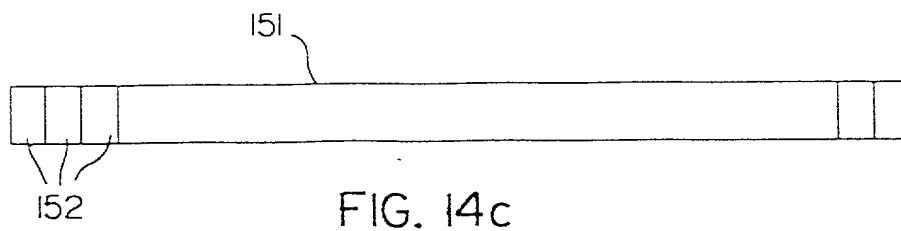
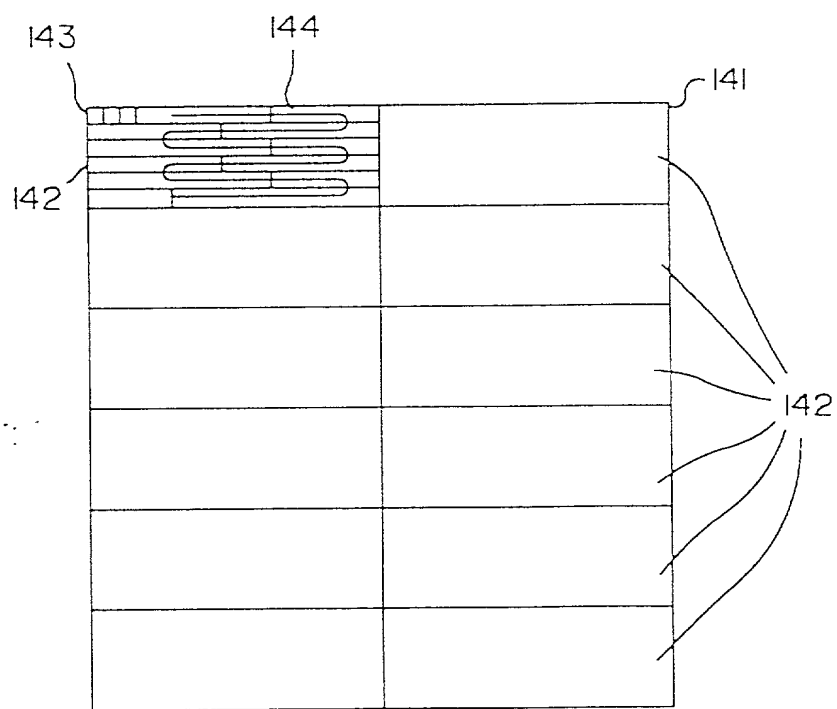
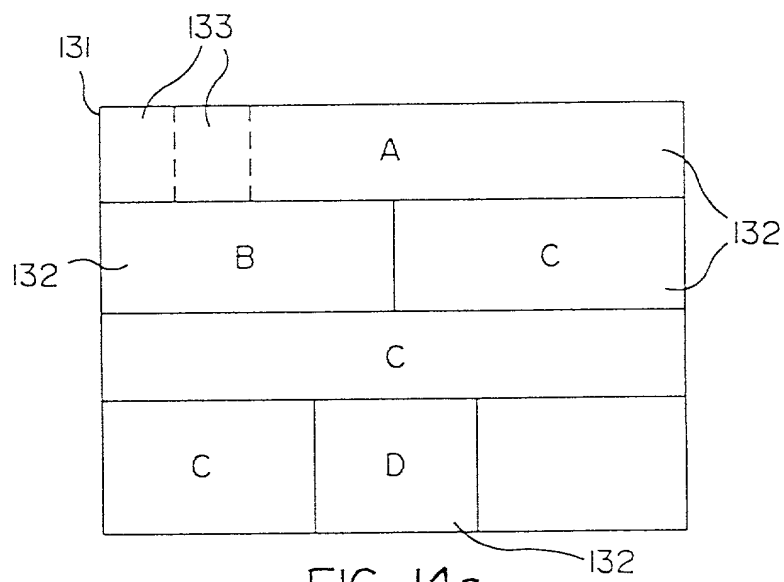


FIG. 13



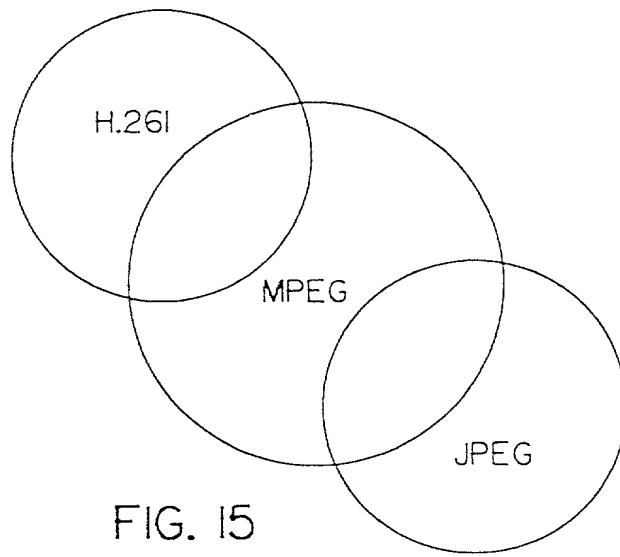


FIG. 15

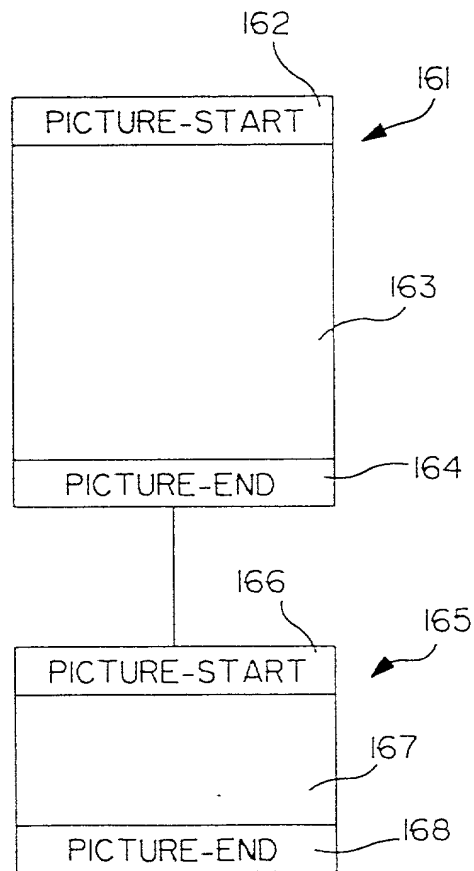
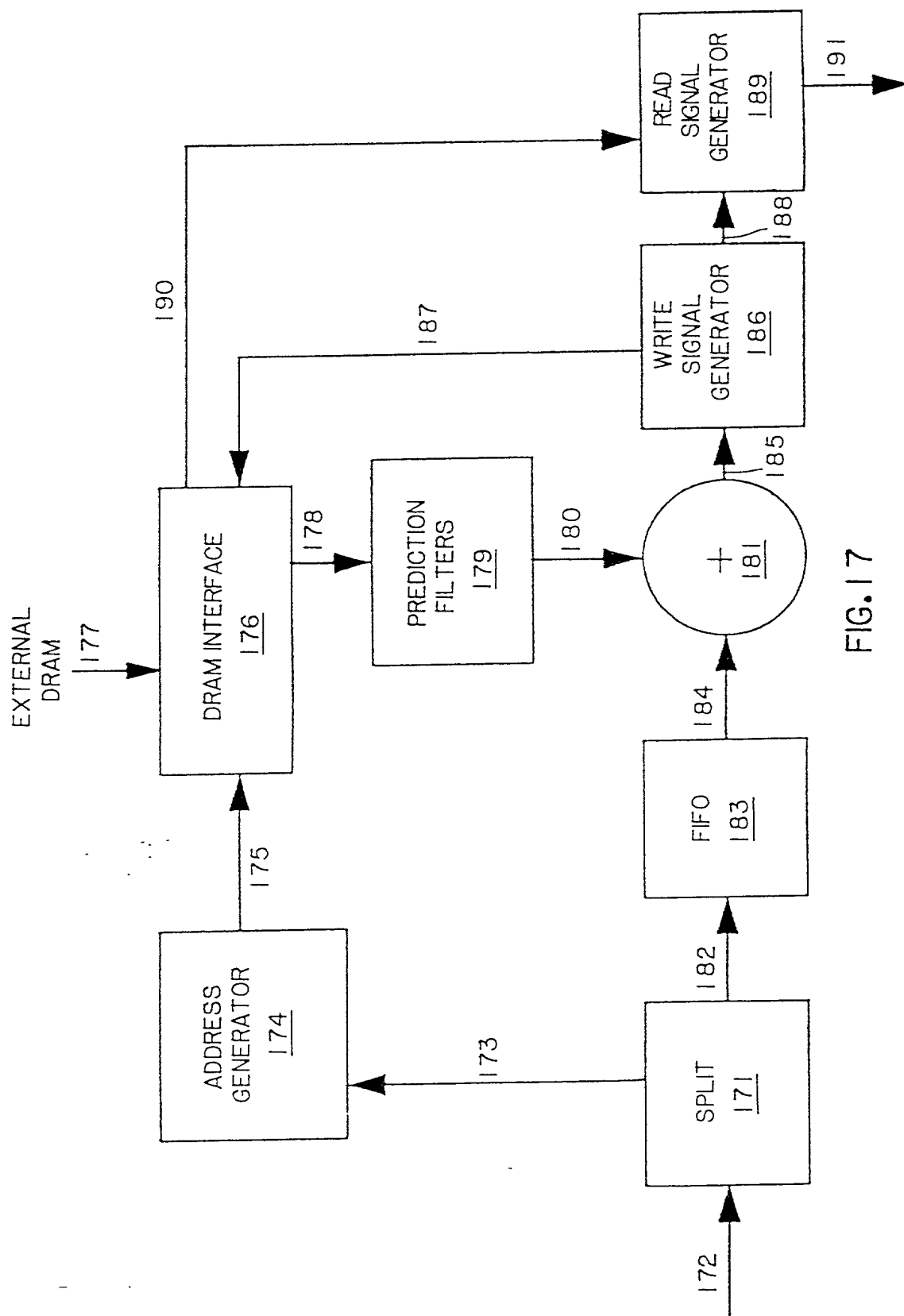


FIG. 16



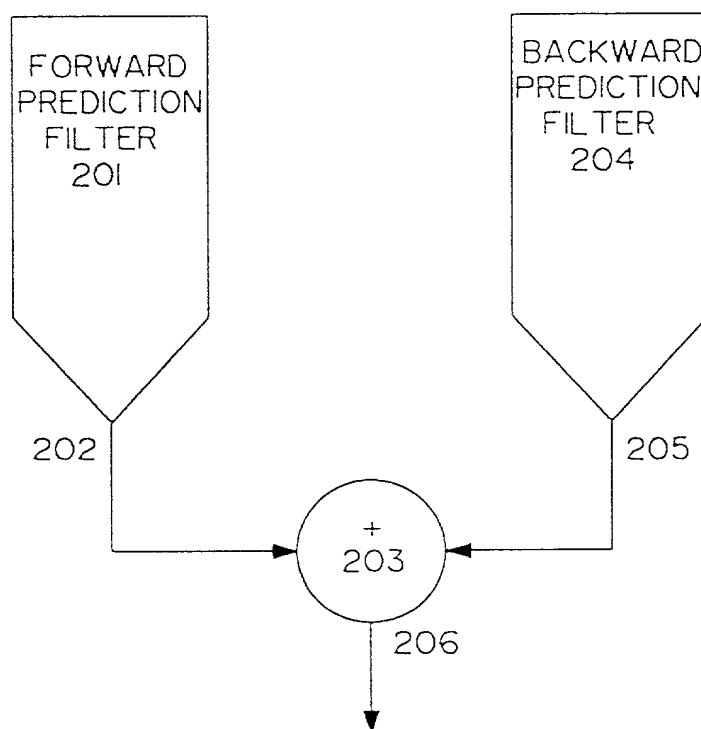


FIG. 18

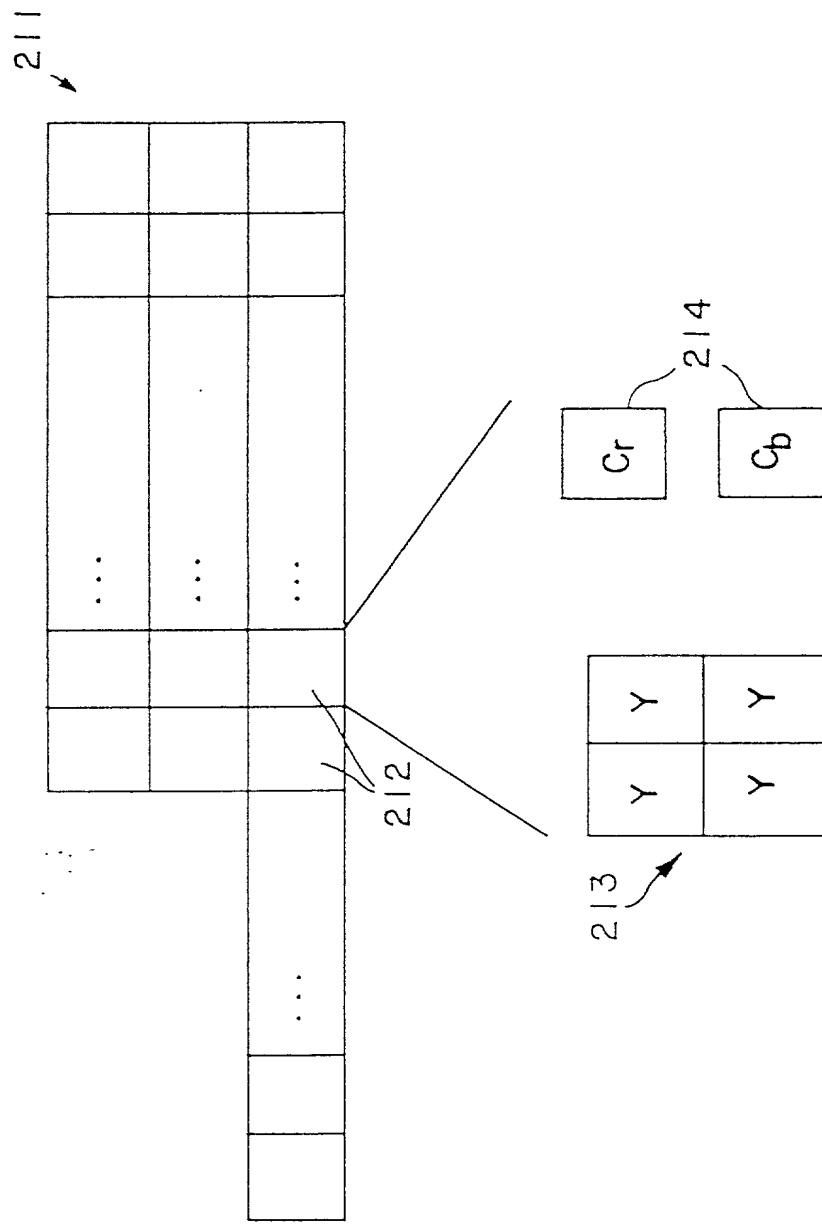


FIG. 19

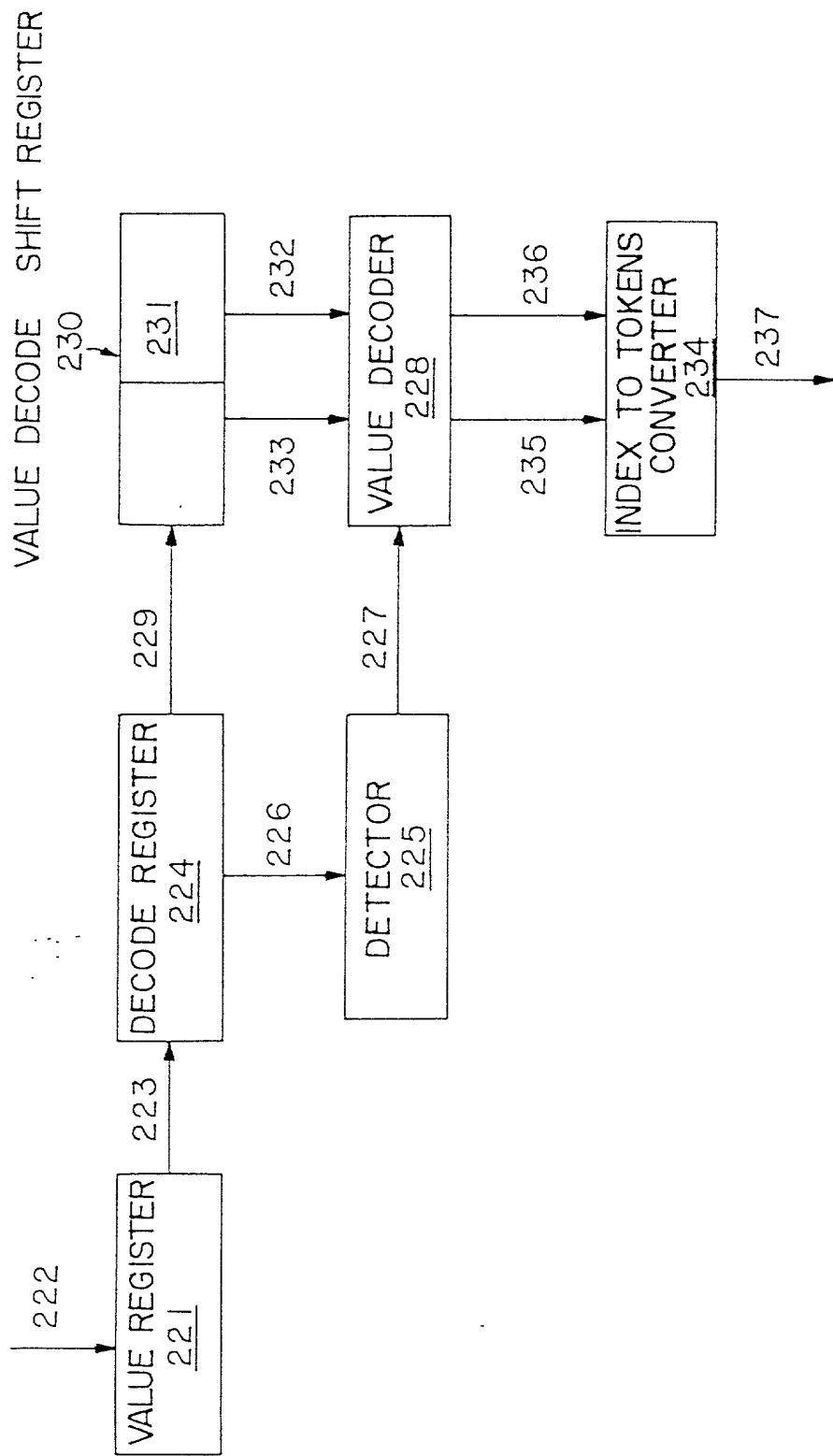


FIG. 20

002T0T"02T63960

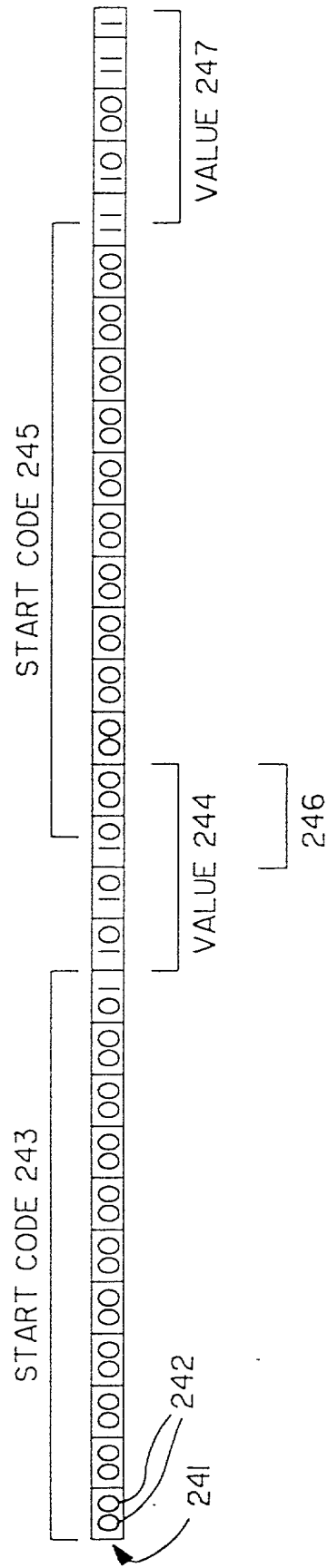


FIG. 21



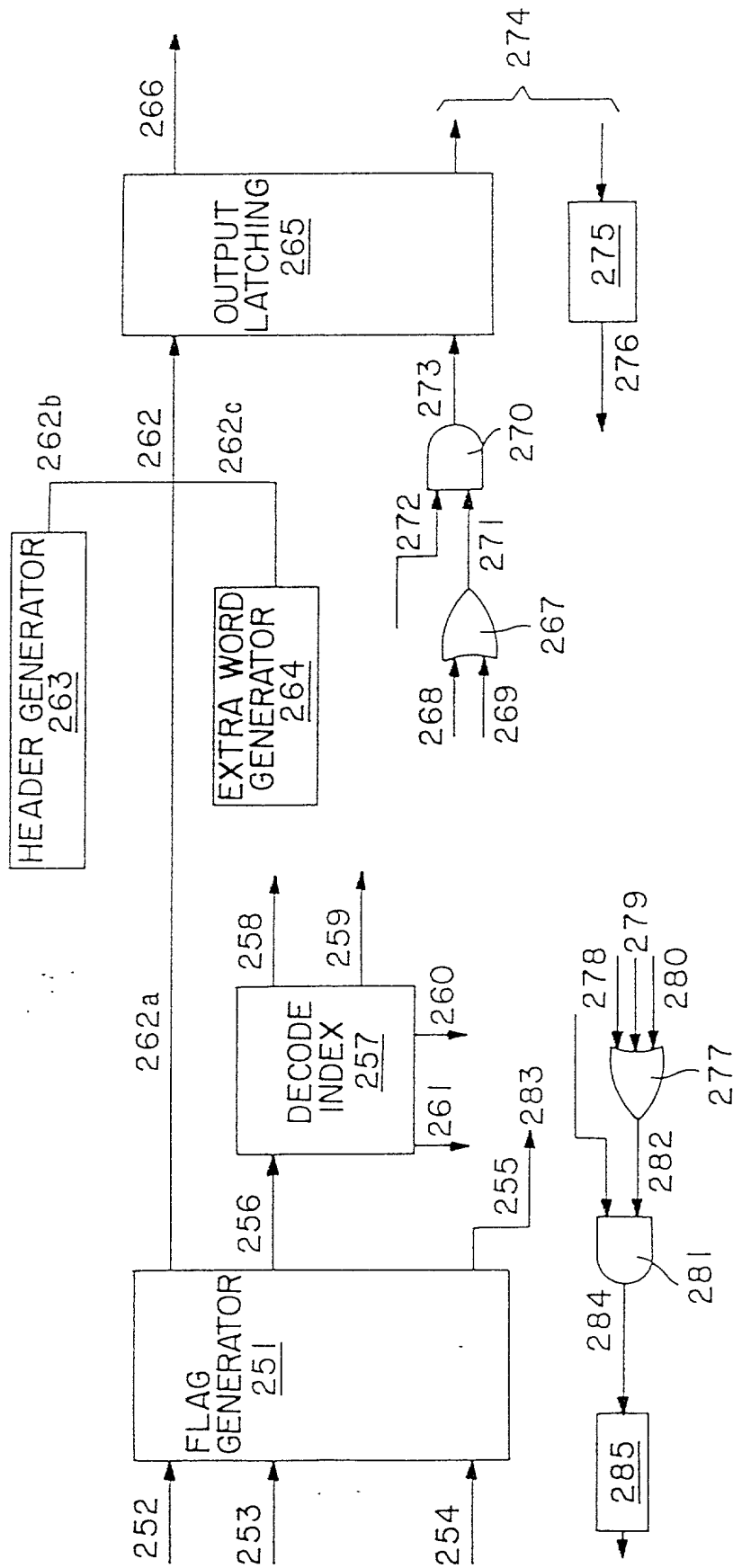


FIG.22

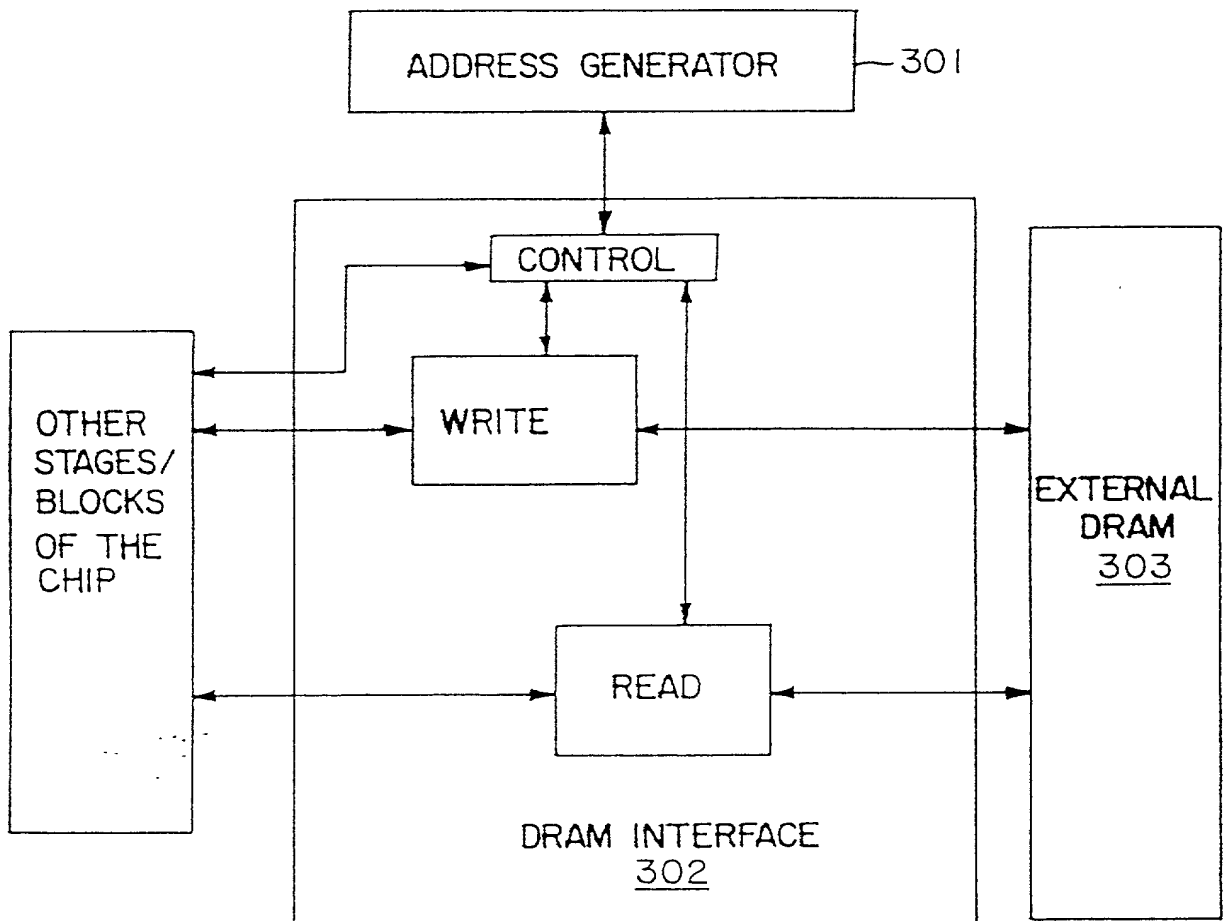


FIG.23

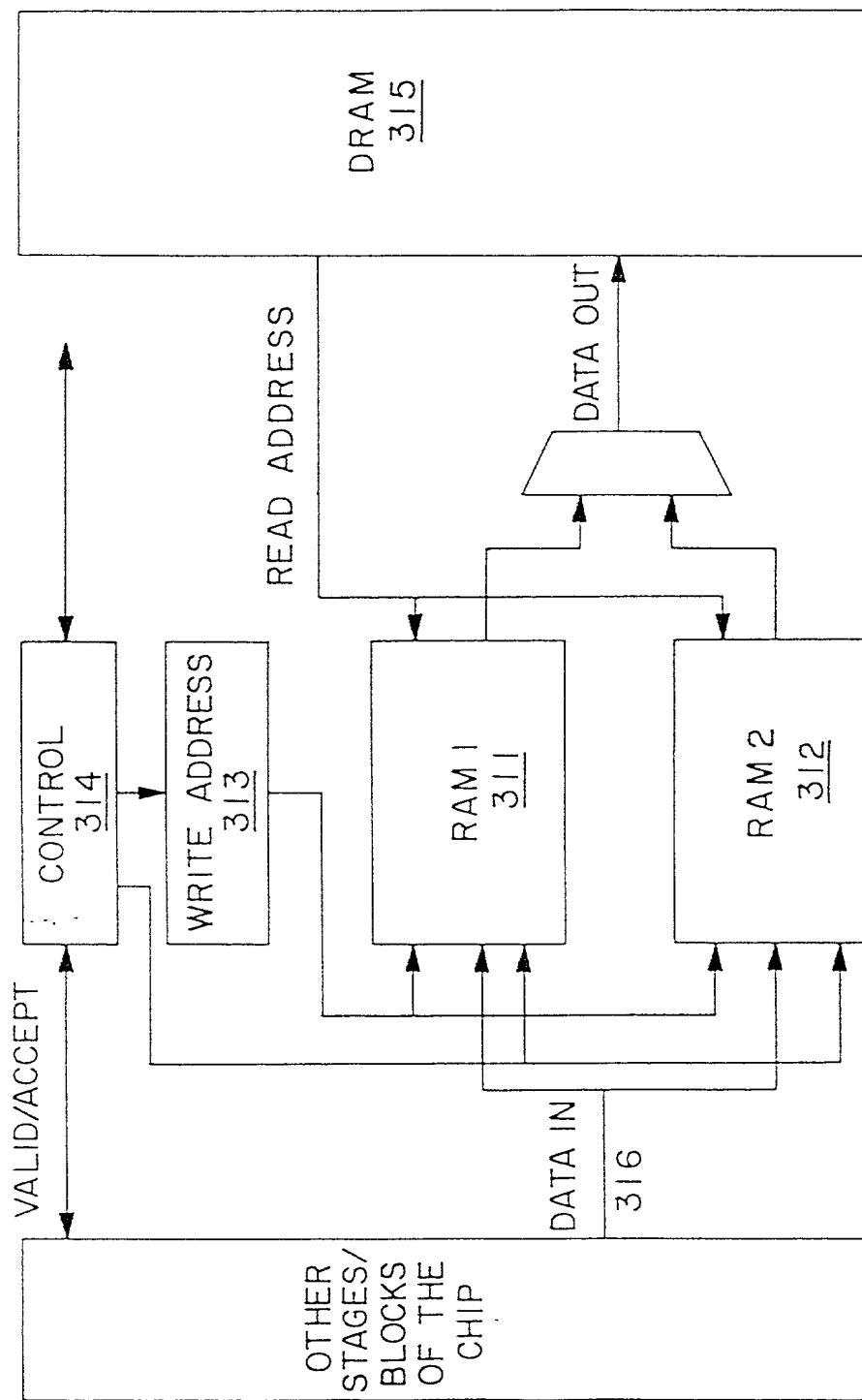


FIG. 24

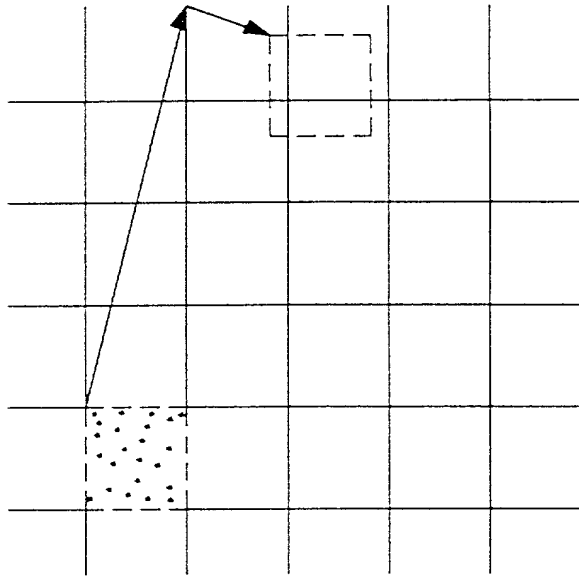


FIG. 25

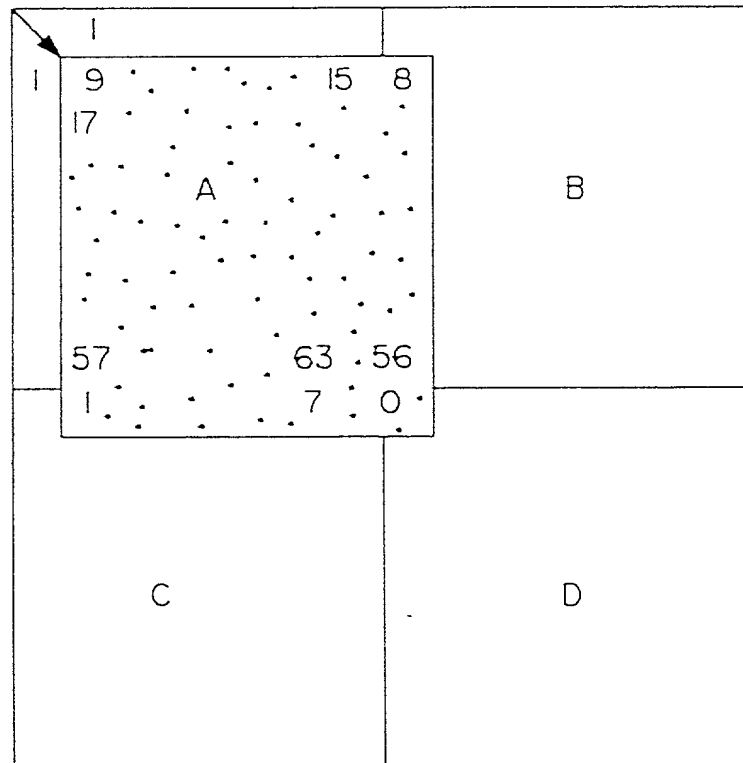


FIG. 26

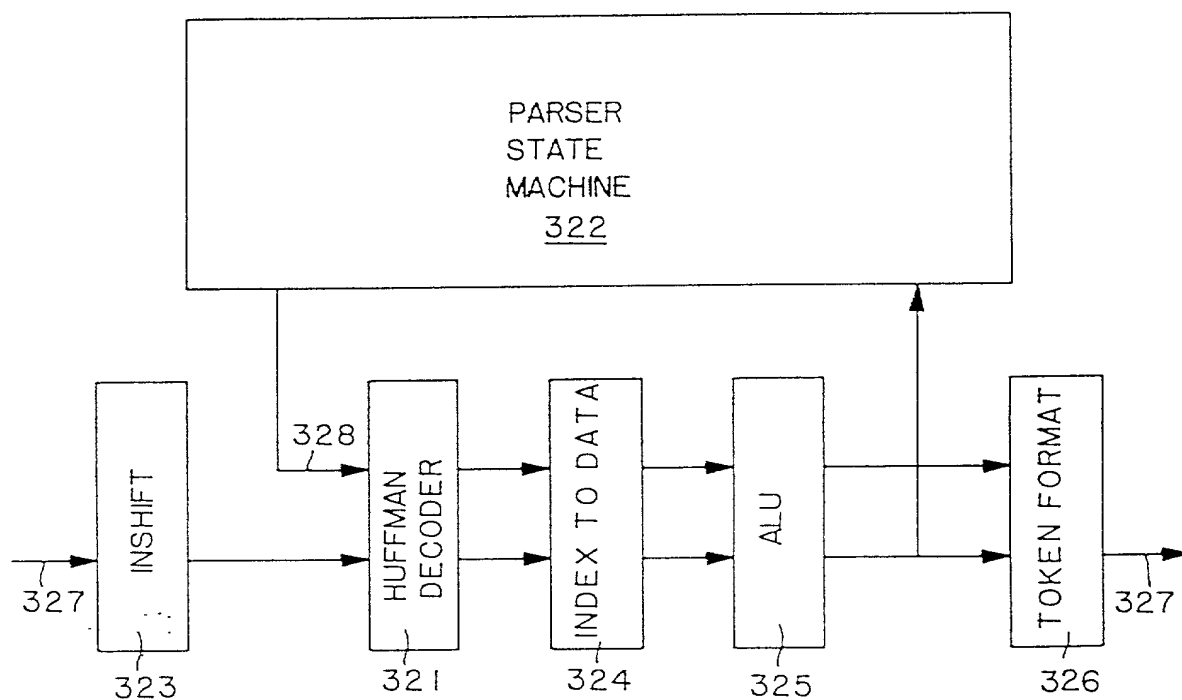


FIG.27

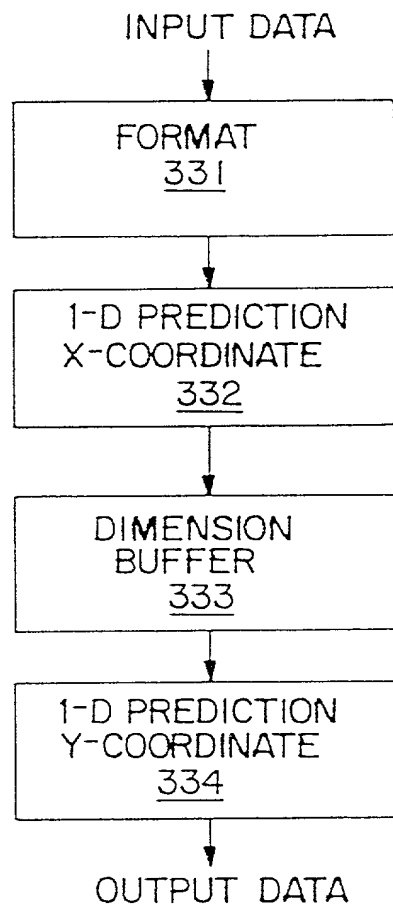


FIG.28

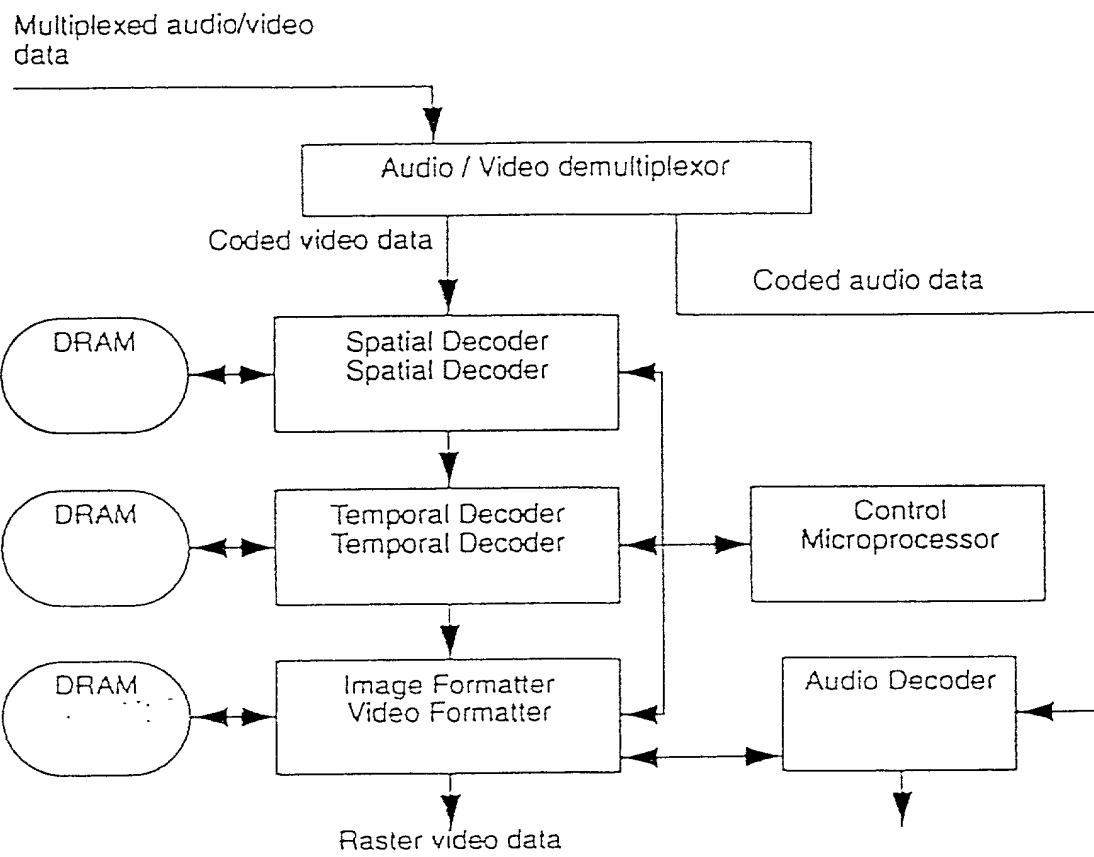


FIG.29

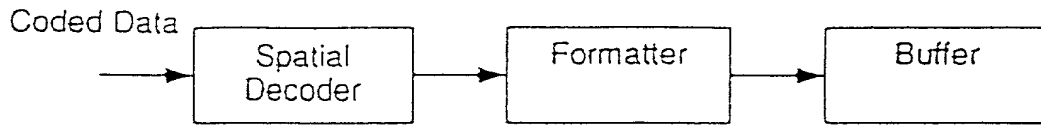


FIG.30

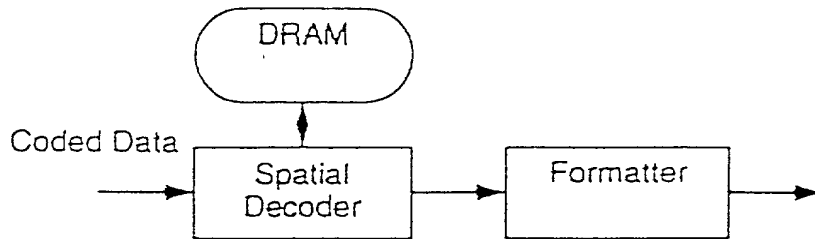


FIG.31

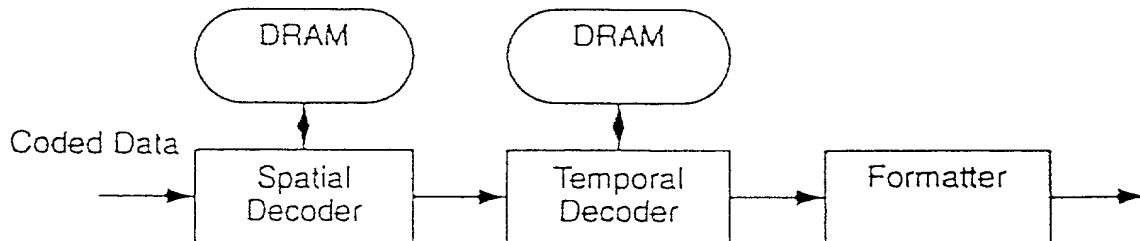


FIG.32



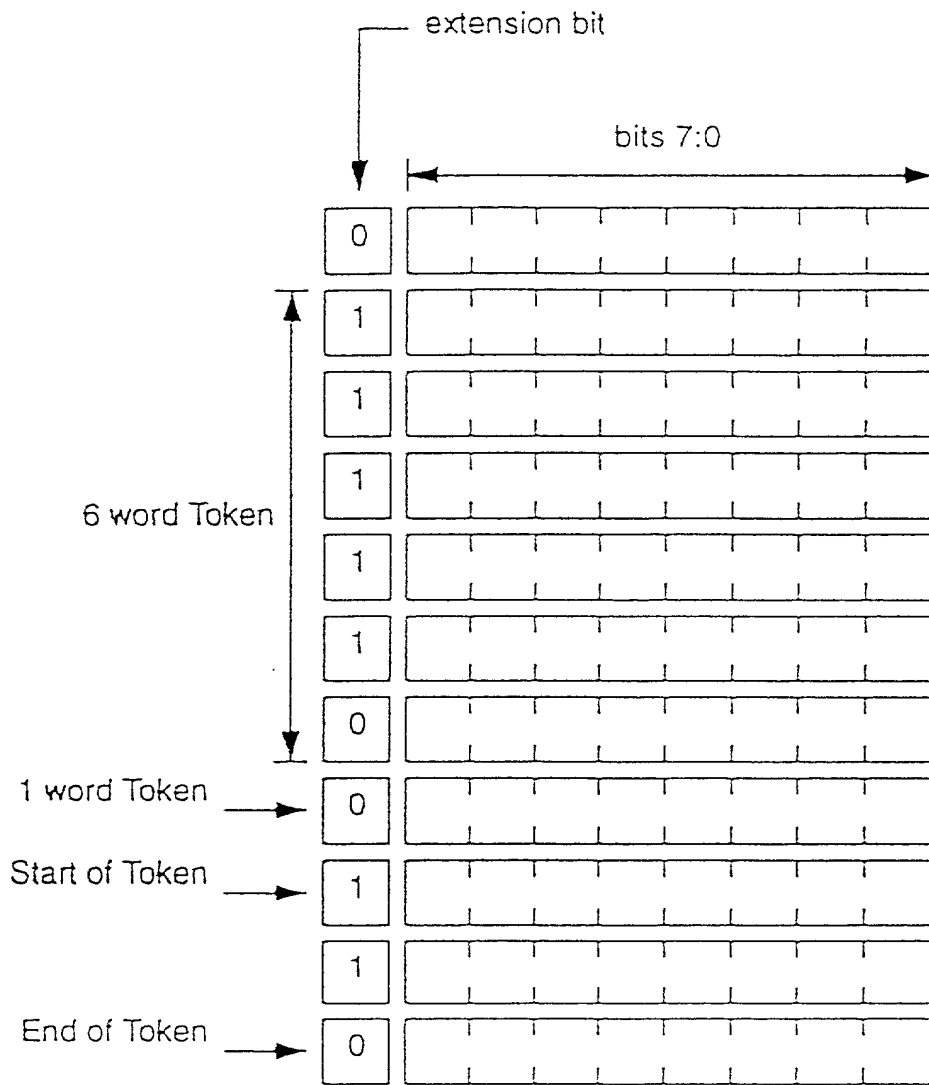


FIG.33

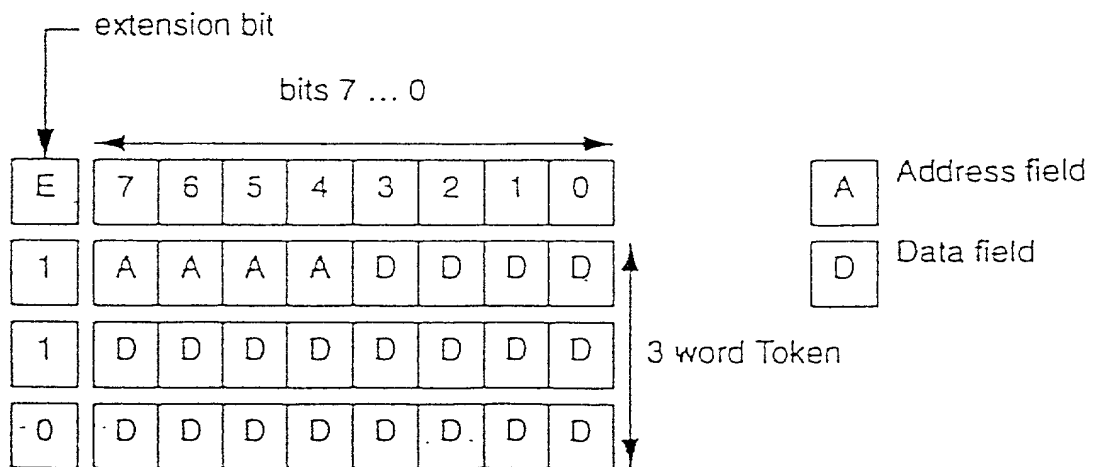


FIG.34

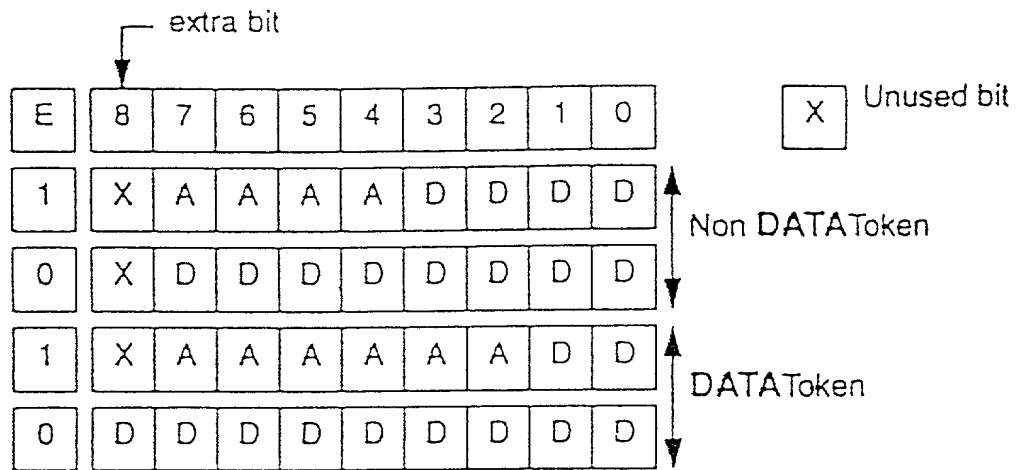
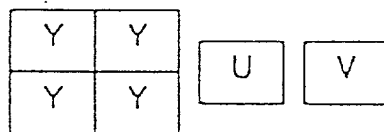


FIG.35



MPEG 4:2:0  
macroblock

FIG.36A



JPEG 2:1:1  
macroblock

FIG.36B

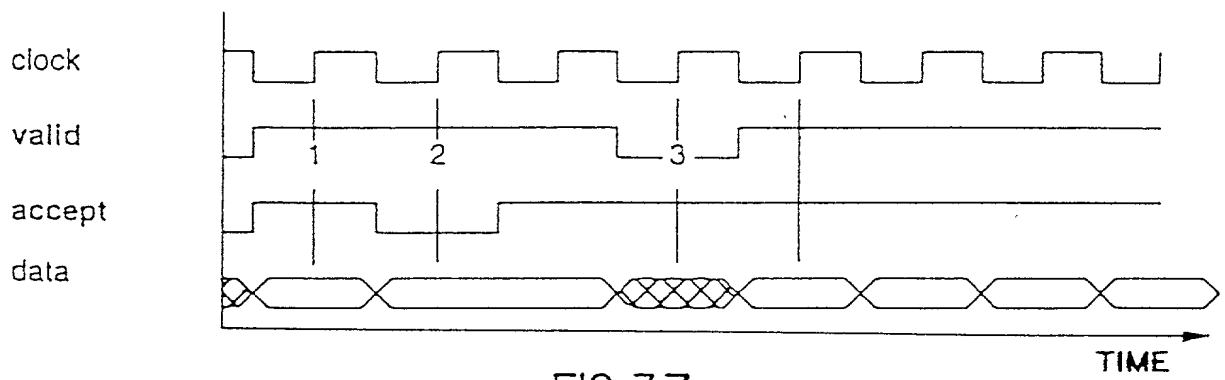


FIG.37

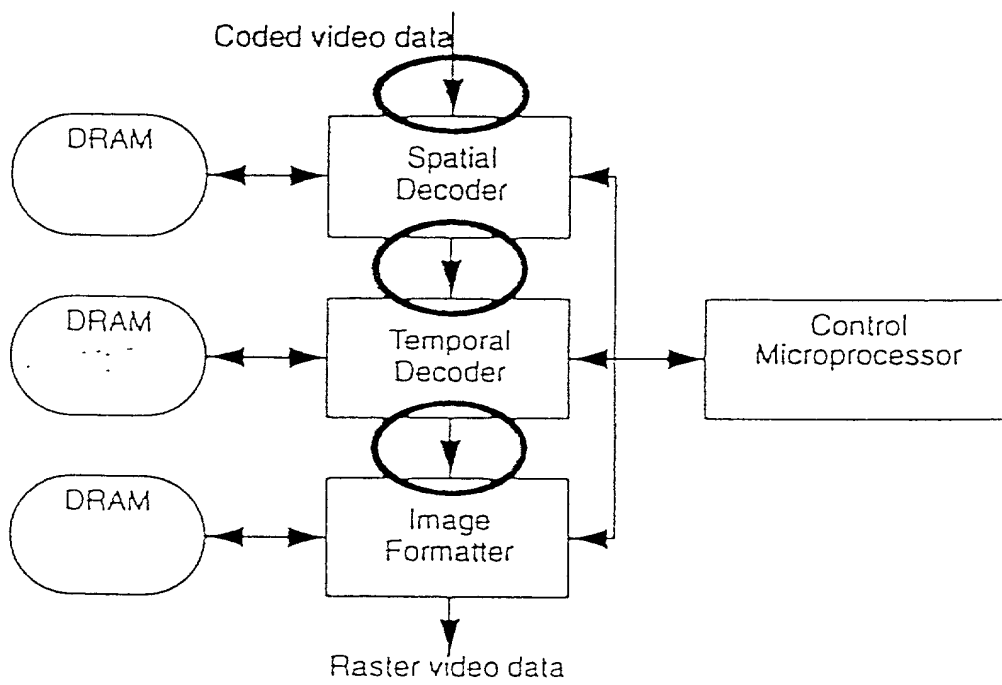


FIG.38

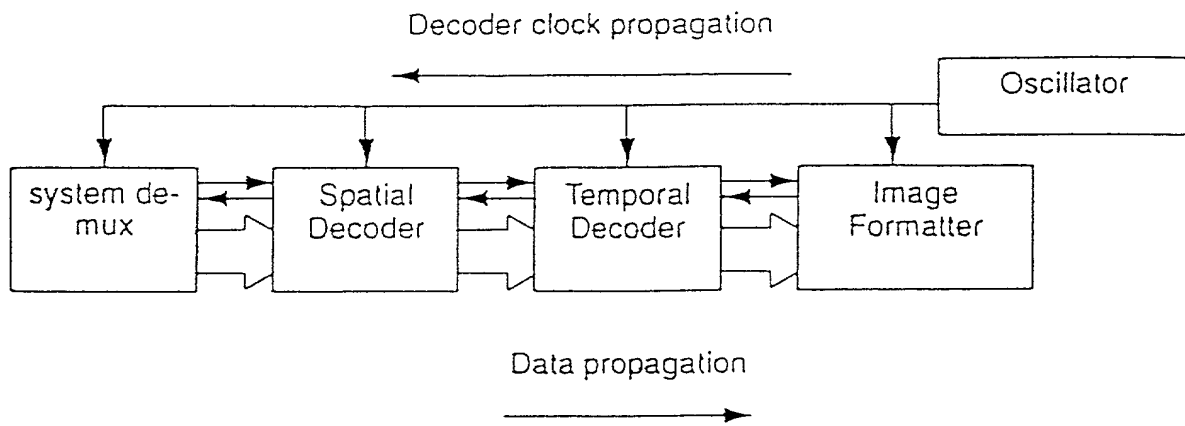


FIG.39

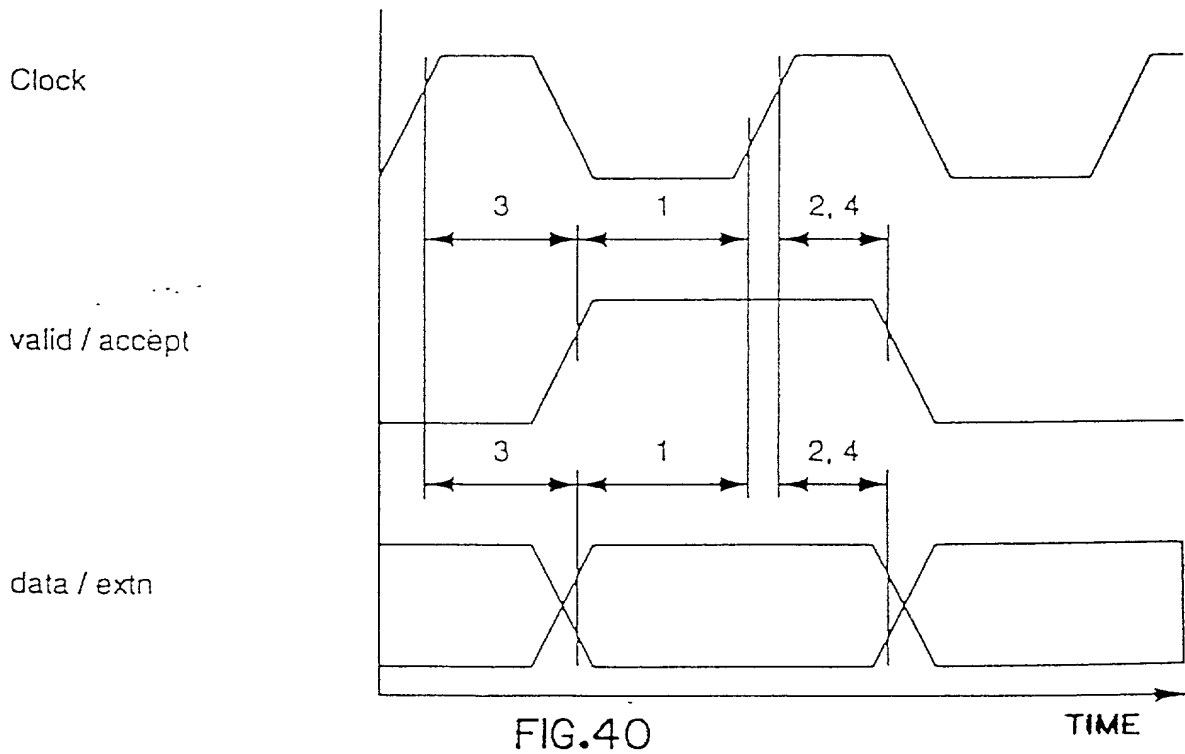


FIG.40



The diagram illustrates the timing relationships for various DRAM control signals and data buses over time. The signals shown are  $\overline{\text{RAS}}$ ,  $\text{DRAM\_addr}[10:0]$ ,  $\overline{\text{WE}}$ ,  $\overline{\text{CAS}}[3:0]$ ,  $\overline{\text{OE}}$ , and  $\text{data}[31:0]$ .

- Row address timing:** This section shows the timing for row address operations. A horizontal arrow labeled '5' indicates the duration from the start of  $\overline{\text{RAS}}$  to the start of  $\overline{\text{WE}}$ . Another horizontal arrow labeled '6' indicates the duration from the start of  $\overline{\text{RAS}}$  to the end of  $\overline{\text{WE}}$ .
- Start of read:** This section shows the timing for a read operation. The  $\text{data}[31:0]$  bus is active during the read cycle, and the  $\overline{\text{OE}}$  signal is active during the read cycle.
- Start of write:** This section shows the timing for a write operation. The  $\text{data}[31:0]$  bus is active during the write cycle, and the  $\overline{\text{WE}}$  signal is active during the write cycle.
- Start of refresh:** This section shows the timing for a refresh operation. The  $\overline{\text{CAS}}[3:0]$  signal is active during the refresh cycle, and the  $\overline{\text{OE}}$  signal is active during the refresh cycle. A horizontal arrow labeled '7' indicates the duration of the refresh cycle.

The diagram is labeled **FIG 4.3** and includes a **TIME** axis at the bottom.

TIME

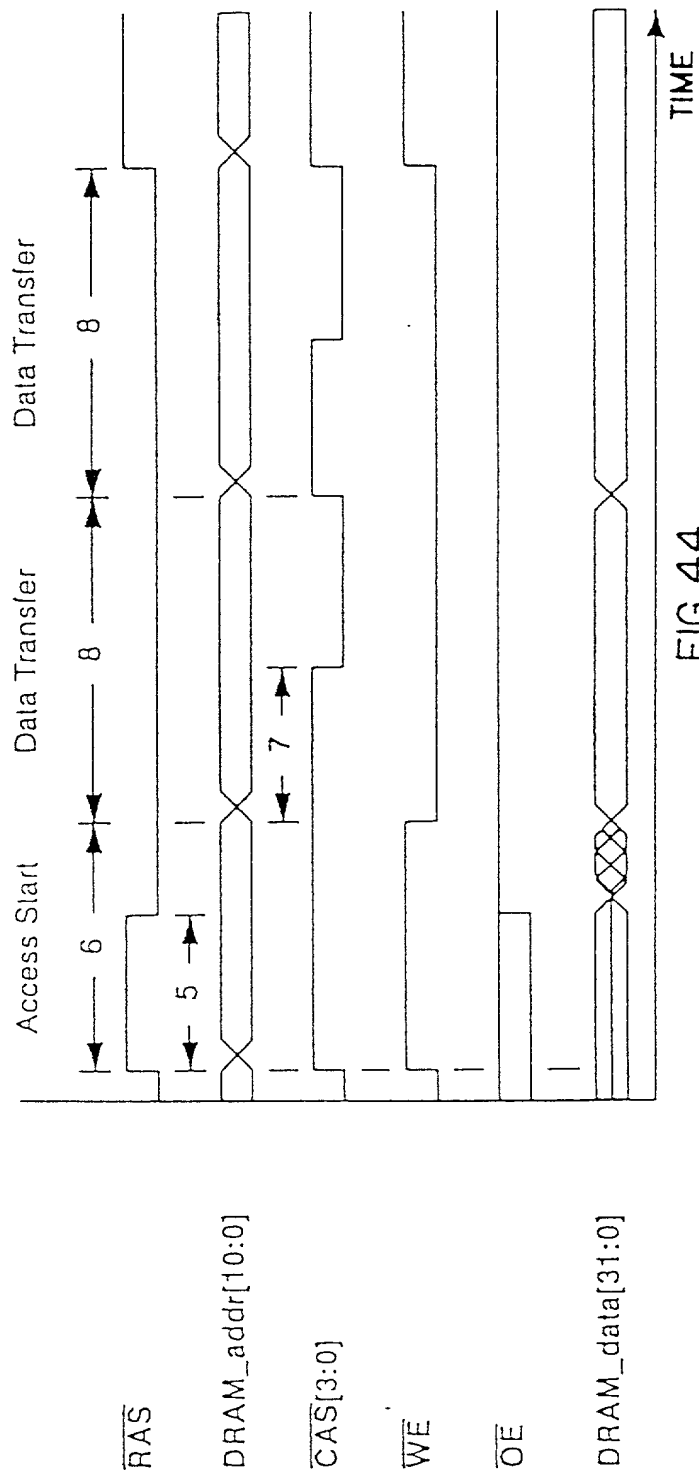


FIG.44

RAS

DRAM\_addr[10:0]

CAS[3:0]

WE

OE

DRAM\_data[31:0]

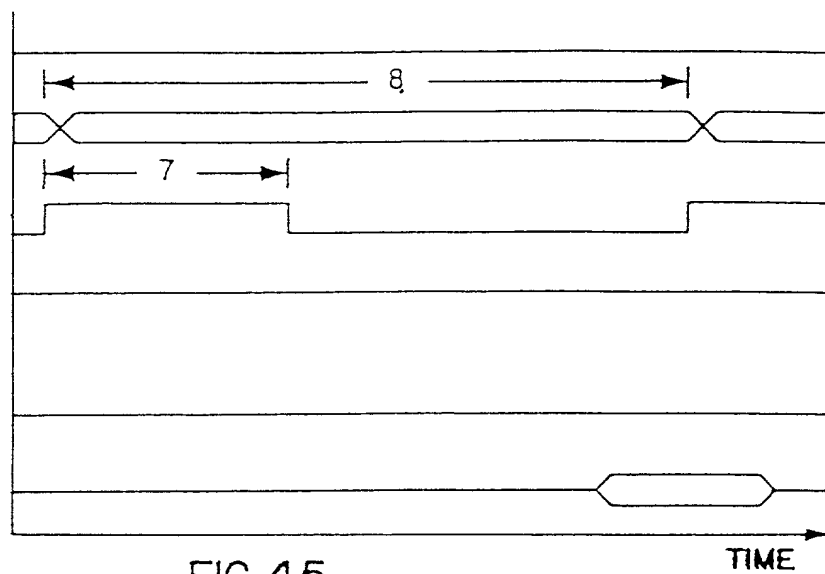


FIG.45

RAS

DRAM\_addr[10:0]

CAS[3:0]

WE

OE

DRAM\_data[31:0]

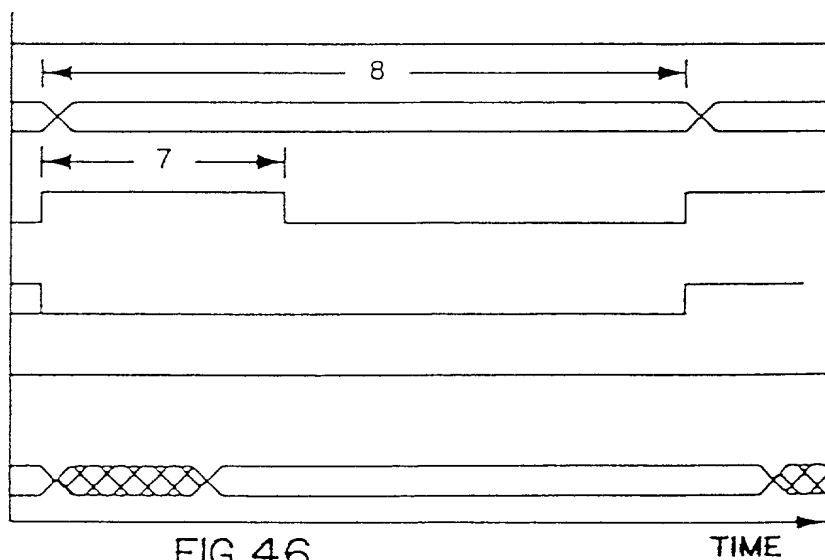


FIG.46



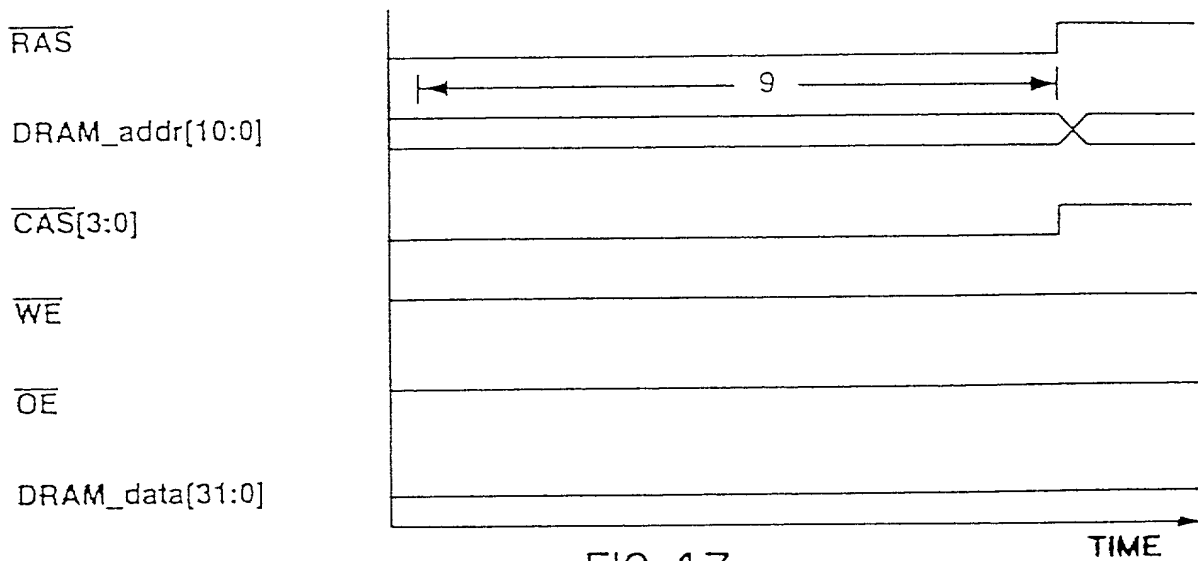


FIG.47

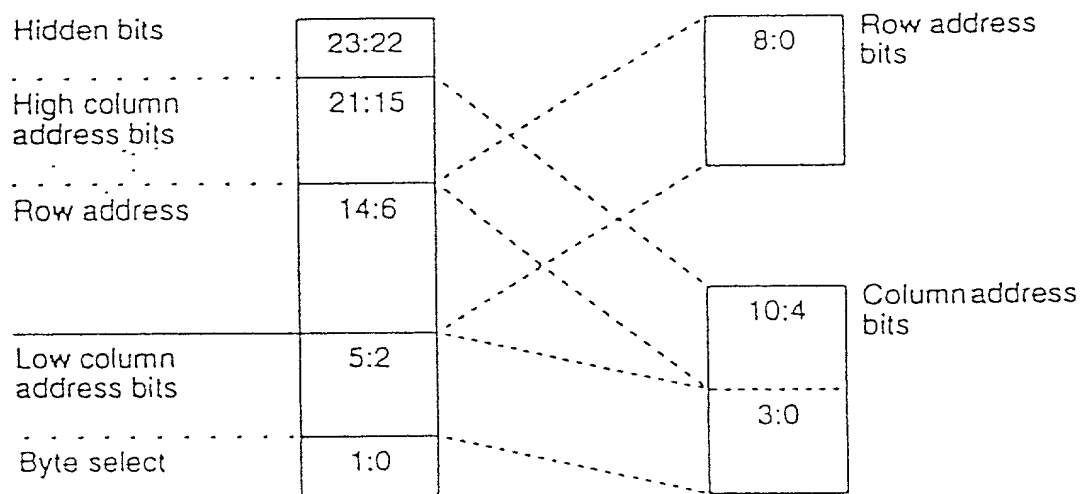


FIG.48

Any signal

The diagram shows a digital signal waveform. The signal transitions from low to high at time 0, remains high for 10 units, transitions to low, remains low for 13 units, transitions to high, remains high for 12 units, transitions to low, remains low for 14 units, transitions to high, remains high for 11 units, and finally transitions to low. The intervals are labeled with numbers above or below the waveform: 10 (high pulse), 13 (low pulse), 12 (high pulse), 14 (low pulse), and 11 (high pulse).

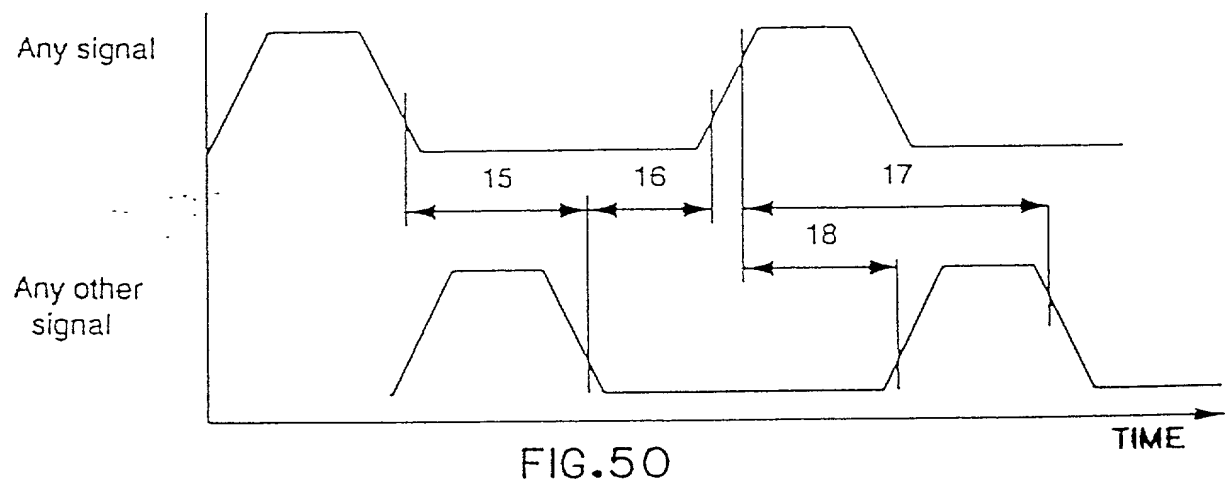
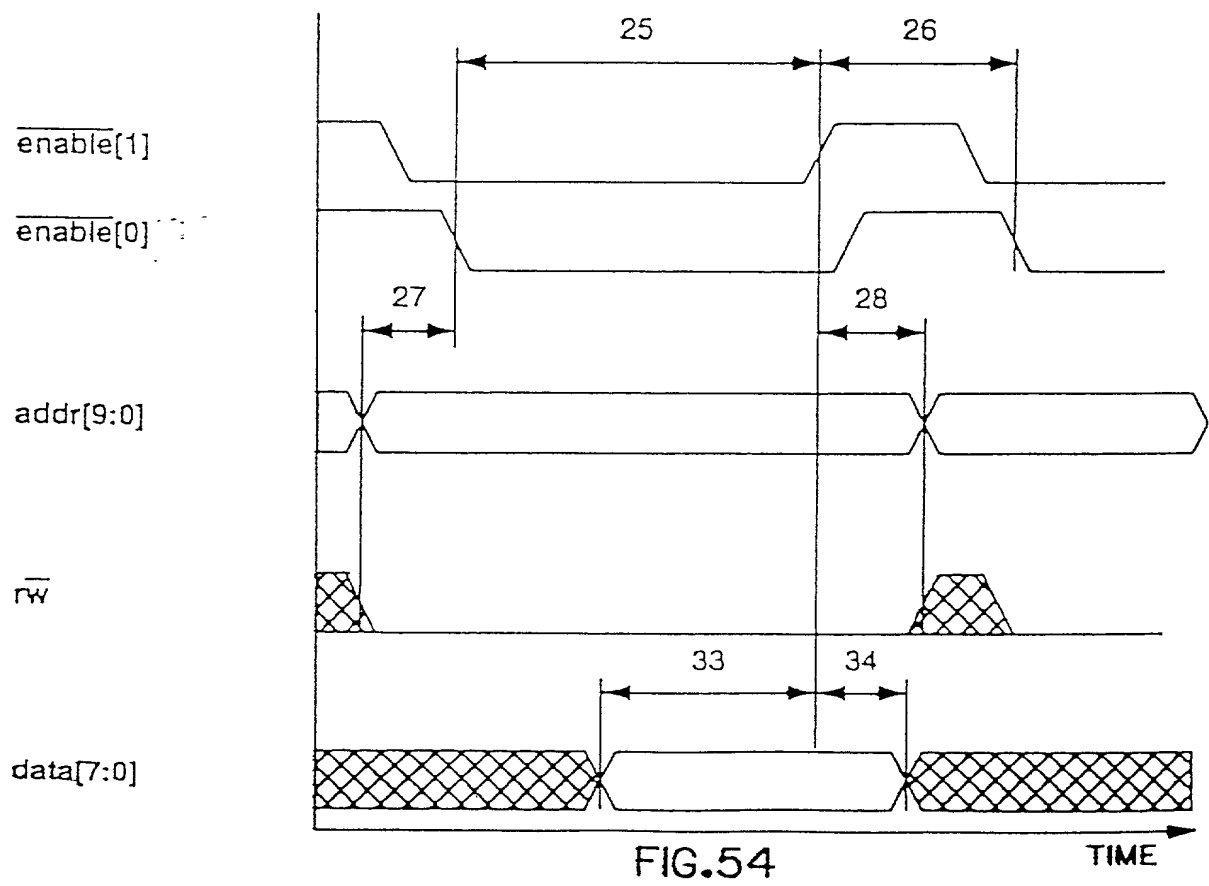
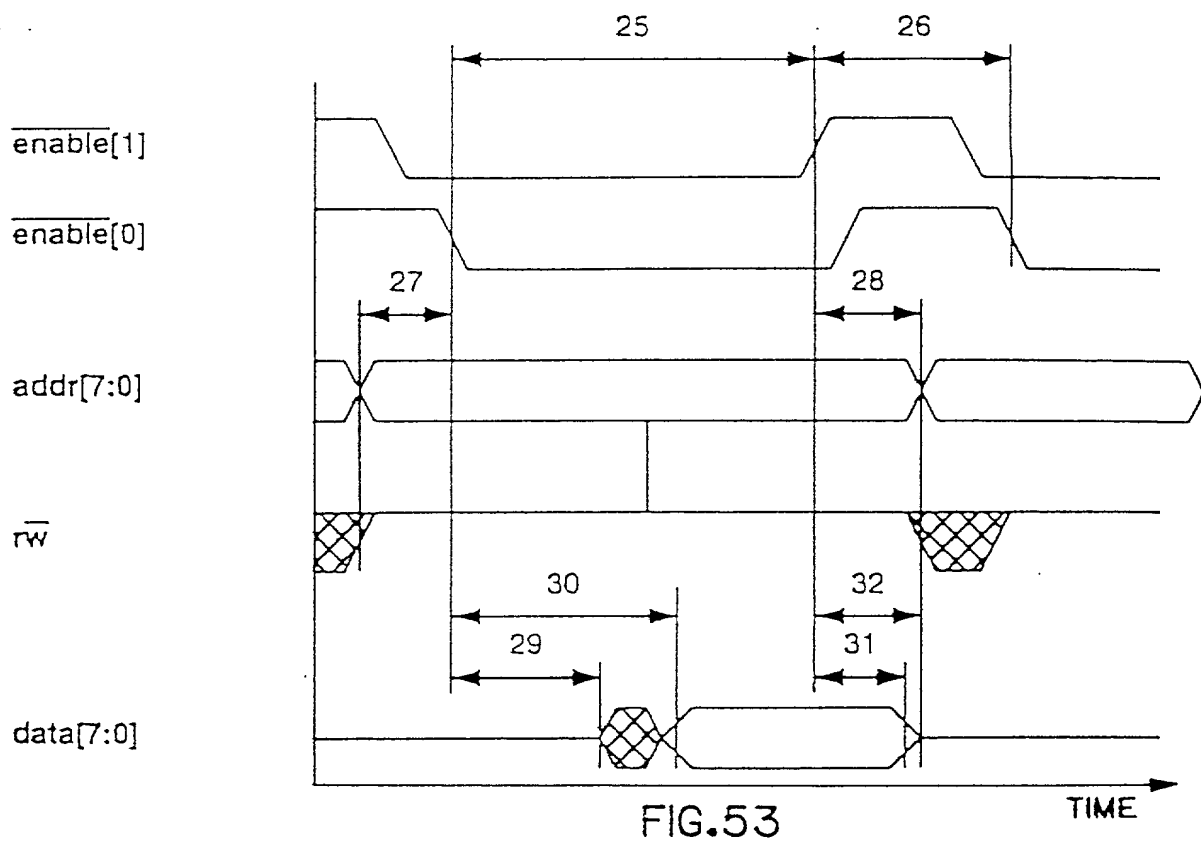


FIG.52



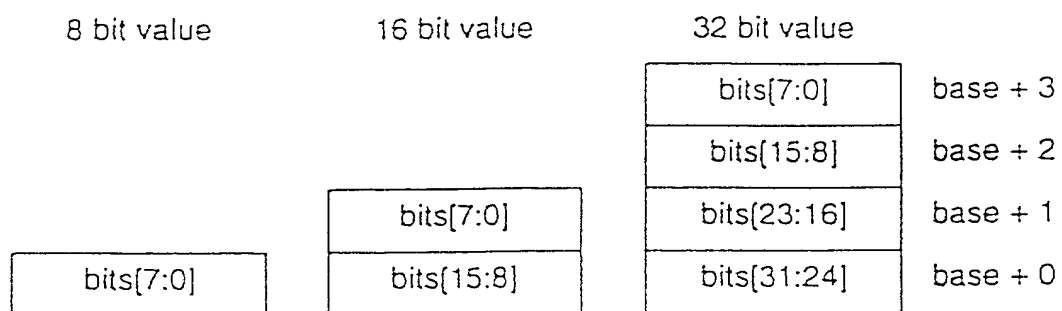


FIG.55

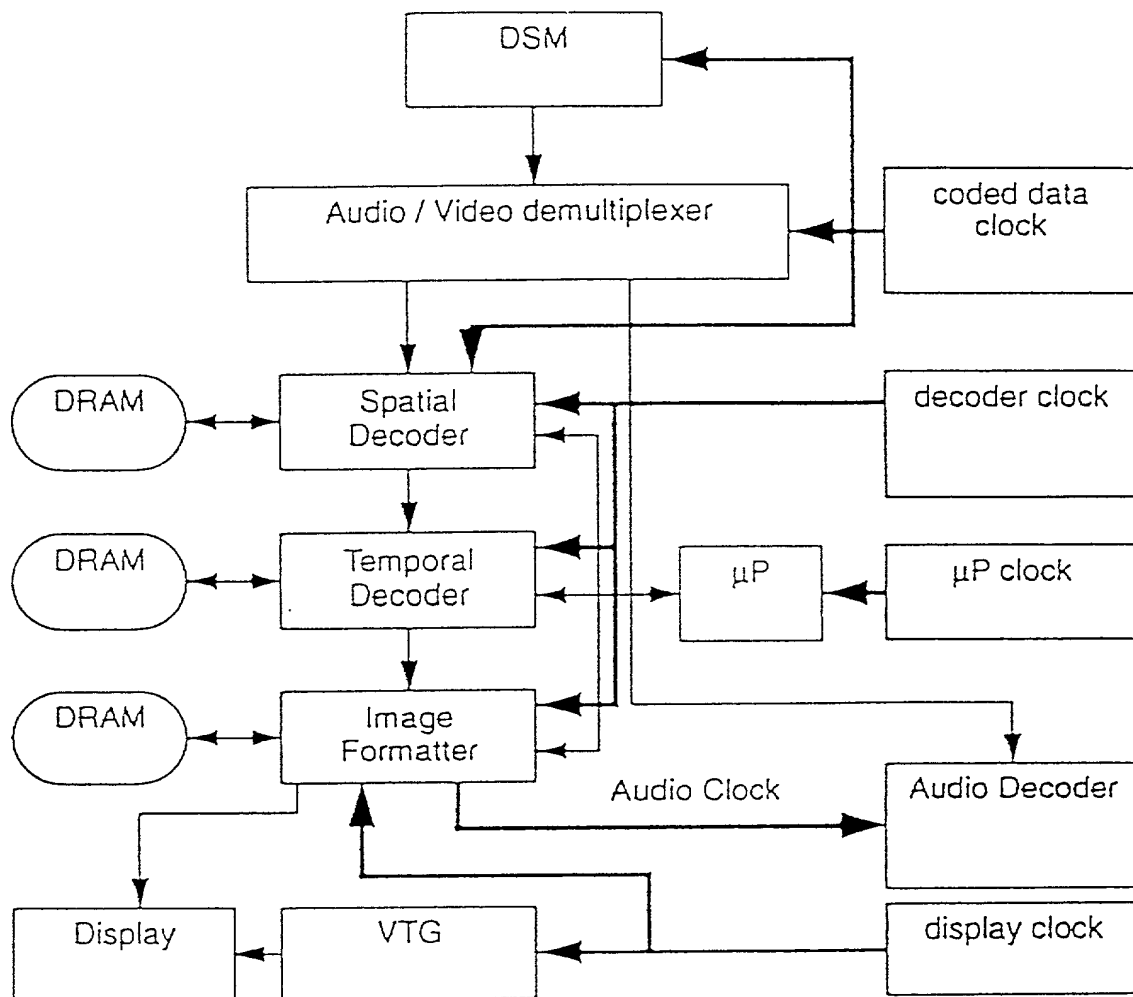


FIG.56

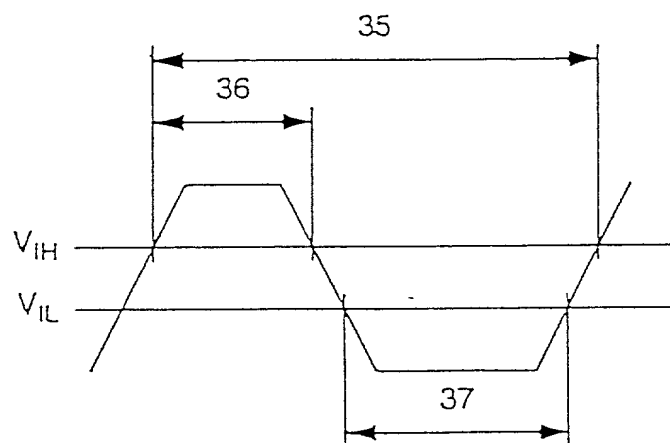
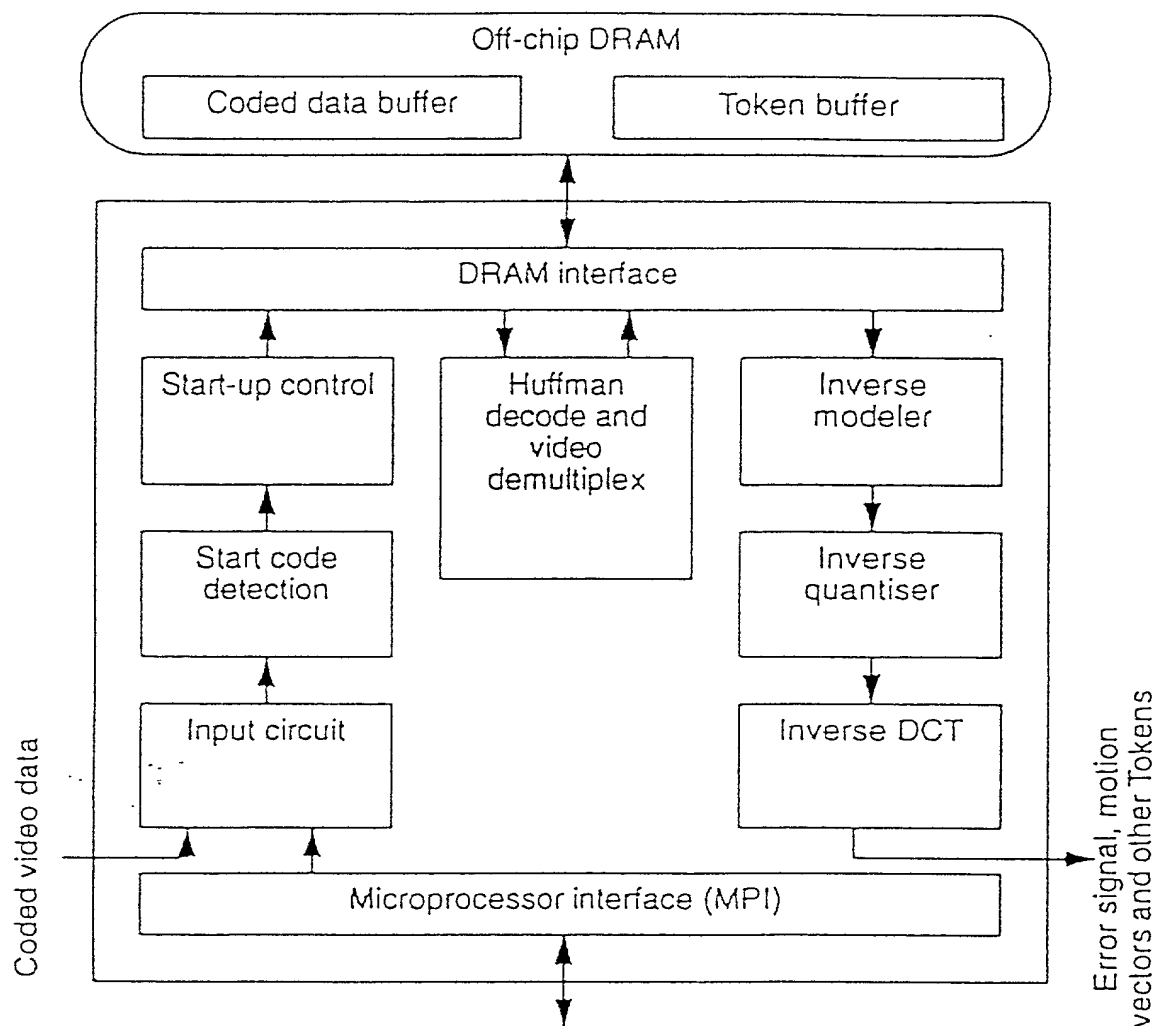


FIG.57



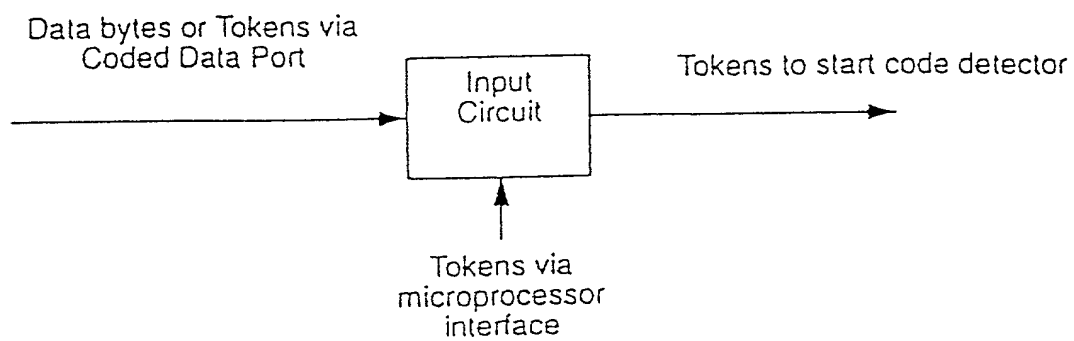
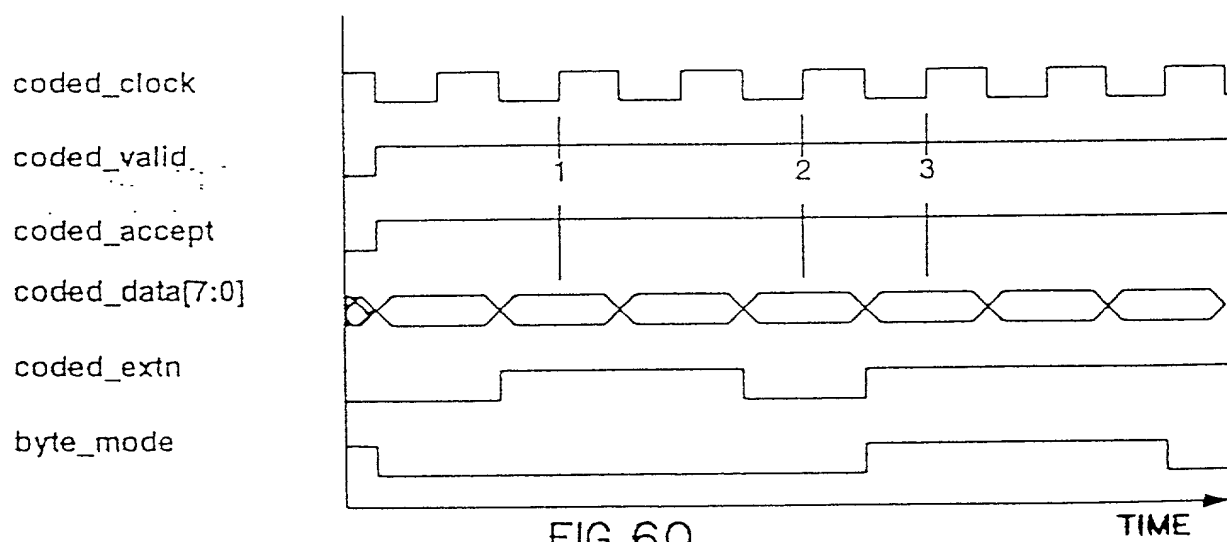


FIG.59





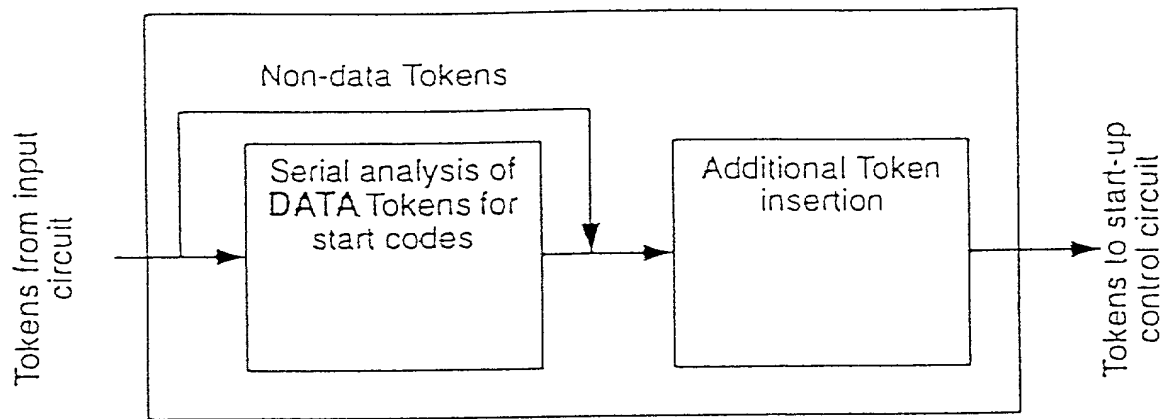


FIG.6 1

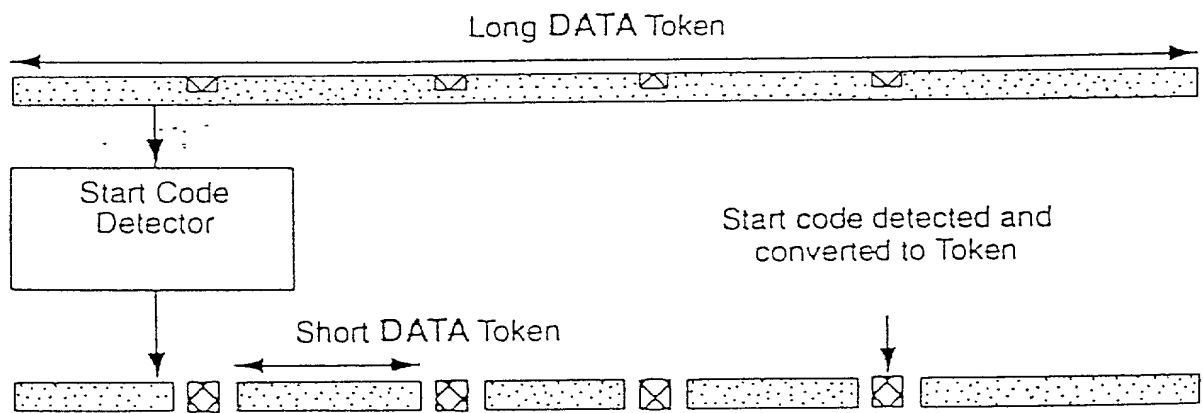


FIG.62

002201 00269950

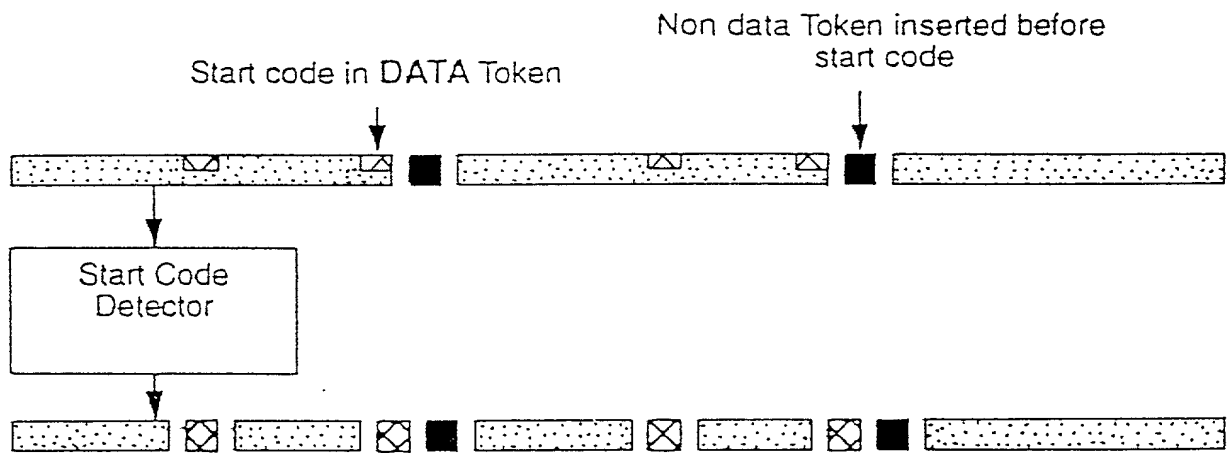


FIG.63

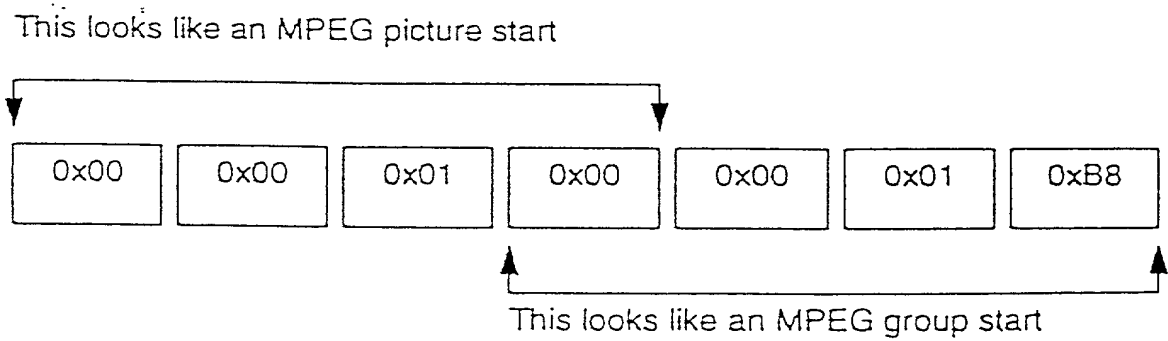


FIG.64

This looks like an MPEG slice start (0x28)

00000000 00000000 00000001 00101000 00000000 00000000 00001000

This looks like the prefix for a non-aligned  
MPEG start code

FIG.65

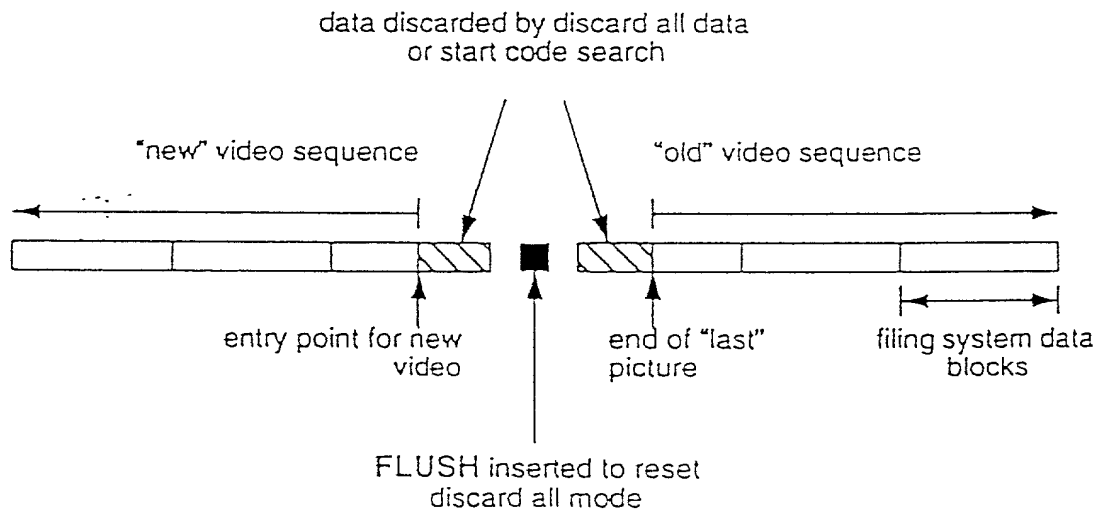


FIG.66

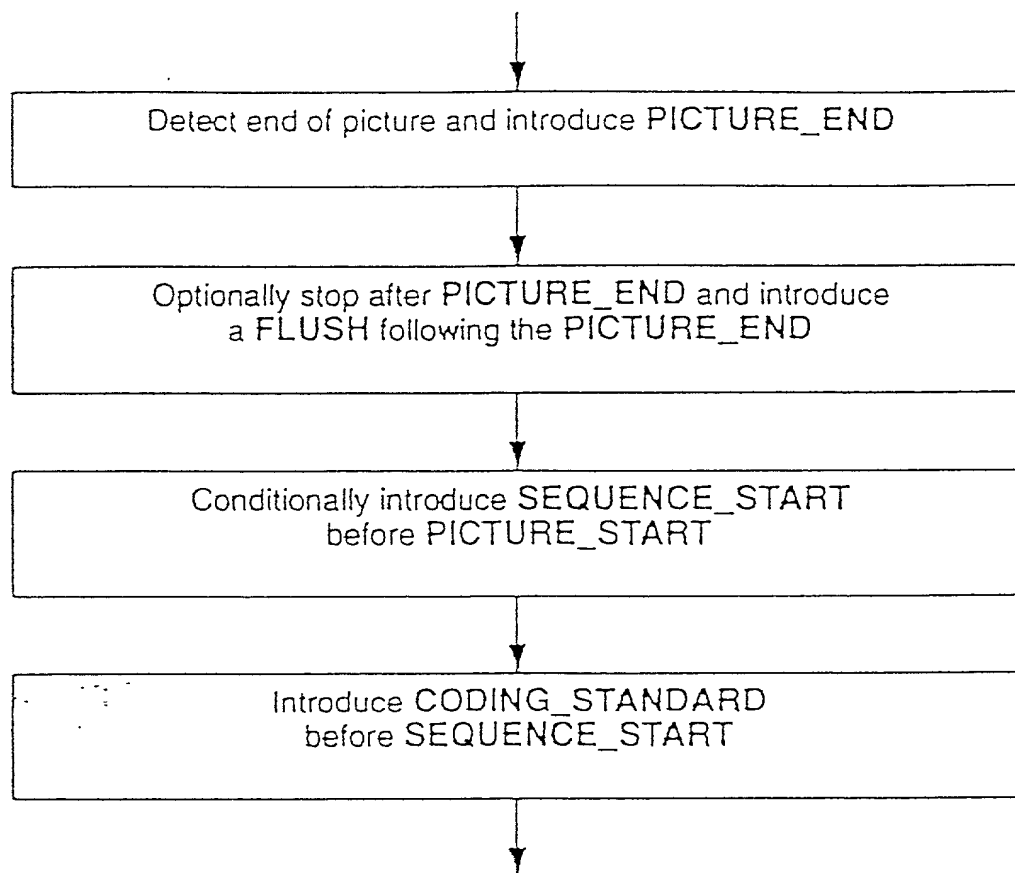


FIG.67

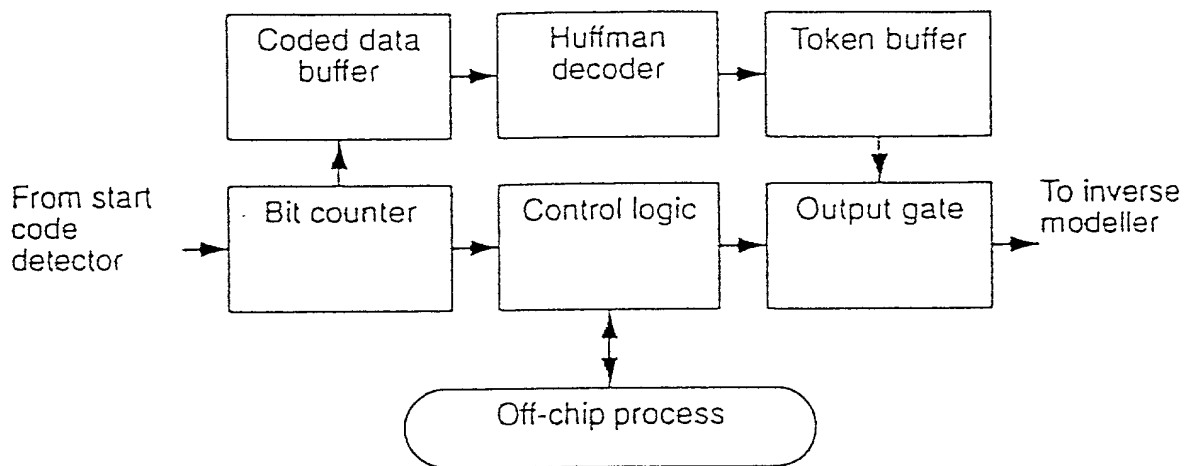


FIG.68

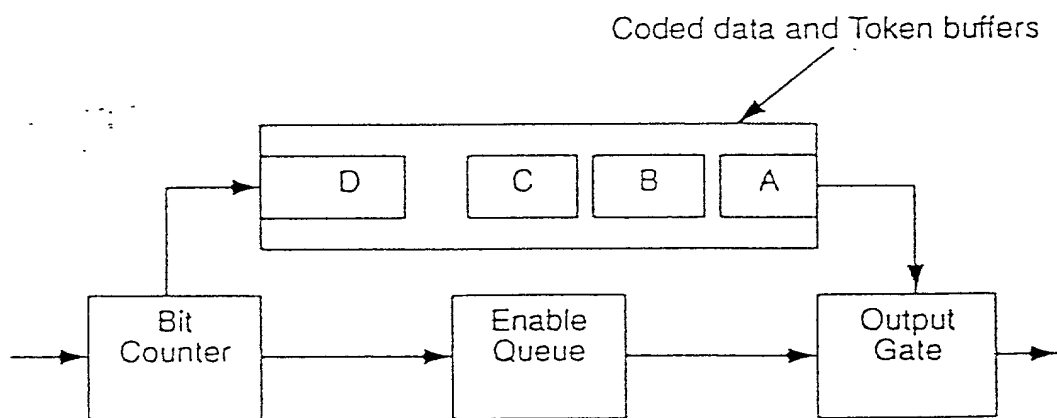


FIG.69

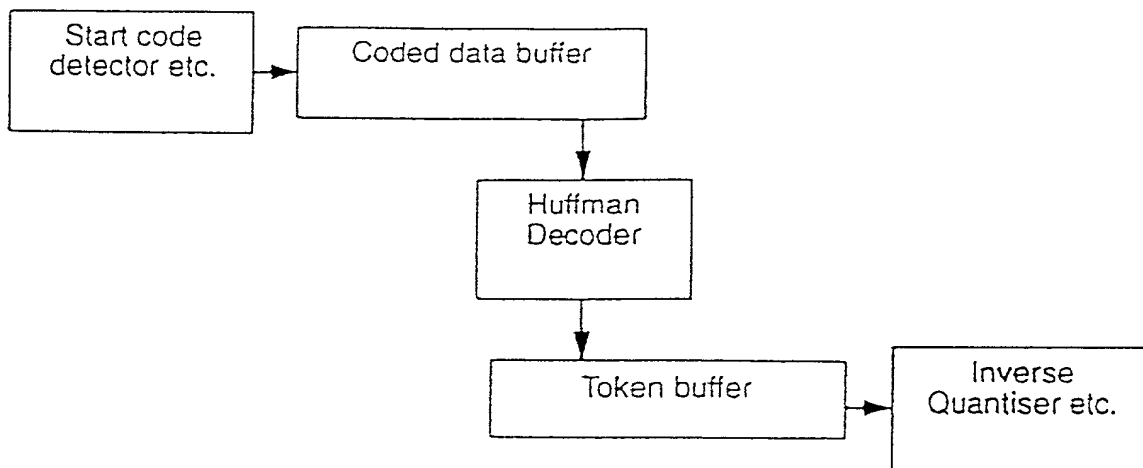


FIG.70

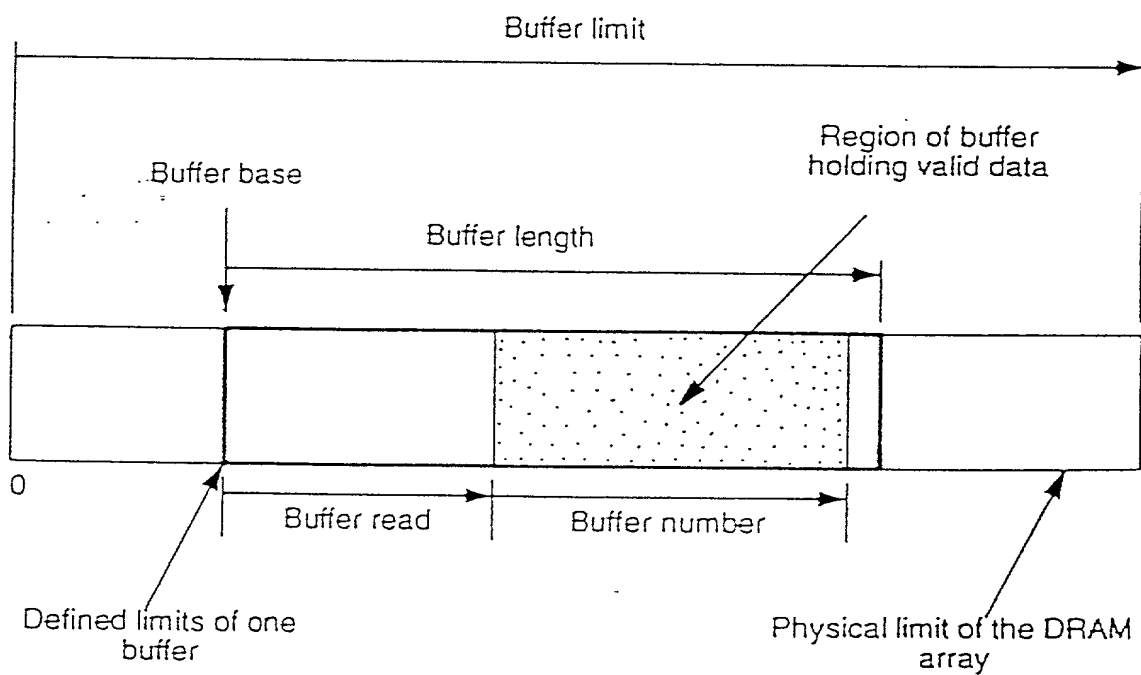


FIG.71

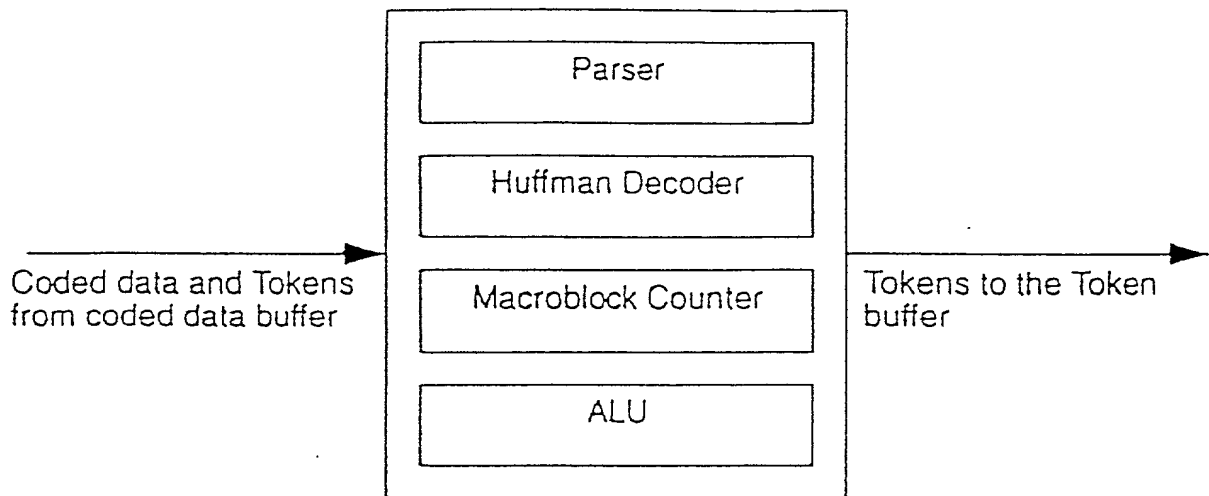


FIG.72

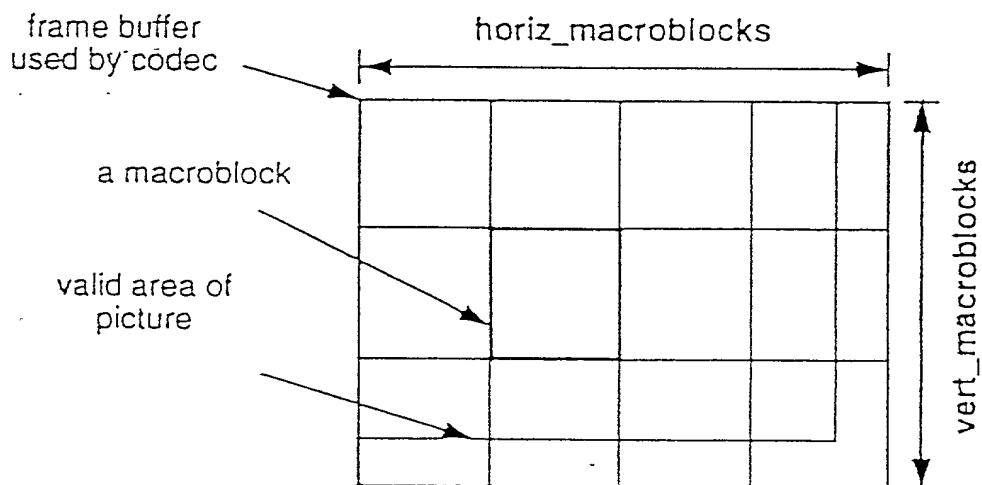


FIG.73

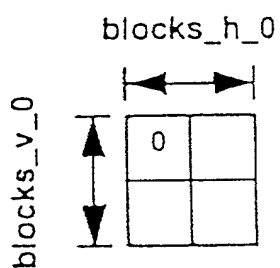


FIG.74A

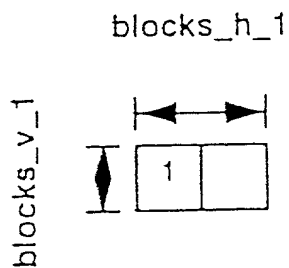


FIG.74B

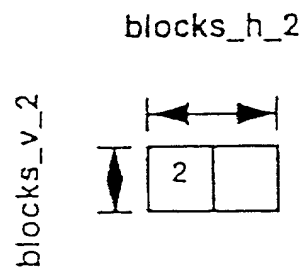


FIG.74C

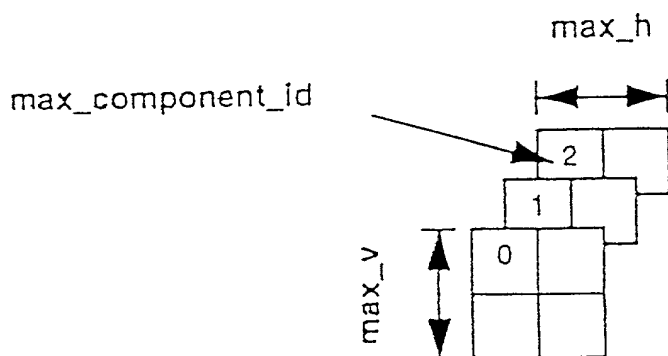


FIG.74D

$$\left\{ \begin{array}{l} \text{horiz\_macroblocks} = \frac{\text{horiz\_pels} + 15}{16} \\ \text{vert\_macroblocks} = \frac{\text{vert\_pels} + 15}{16} \end{array} \right.$$

FIG.75



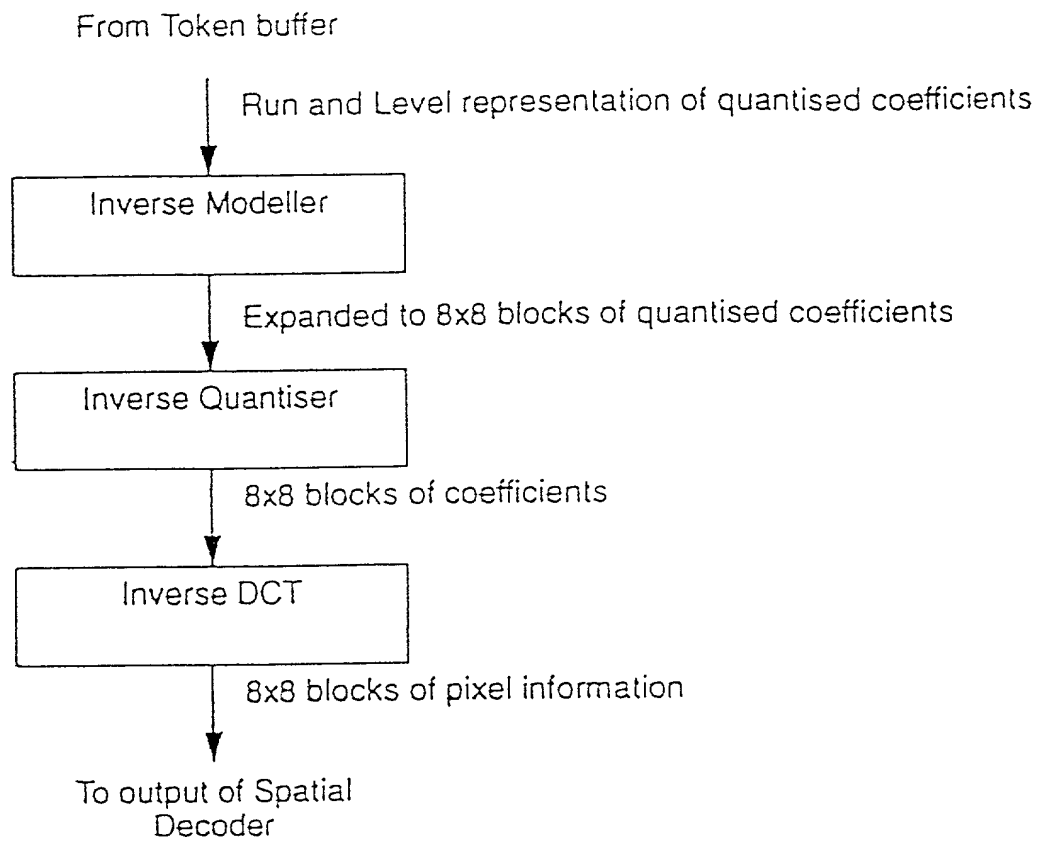


FIG.76

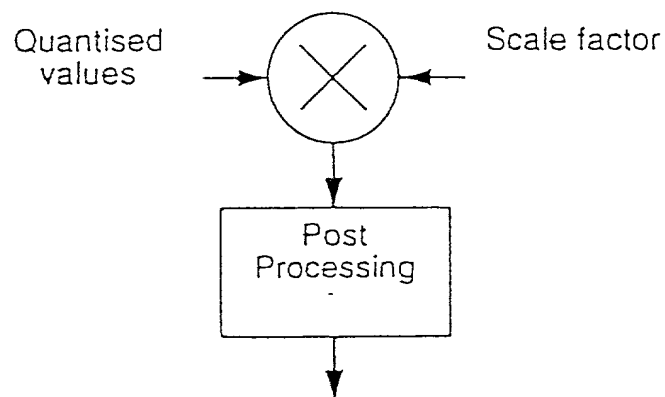


FIG.77

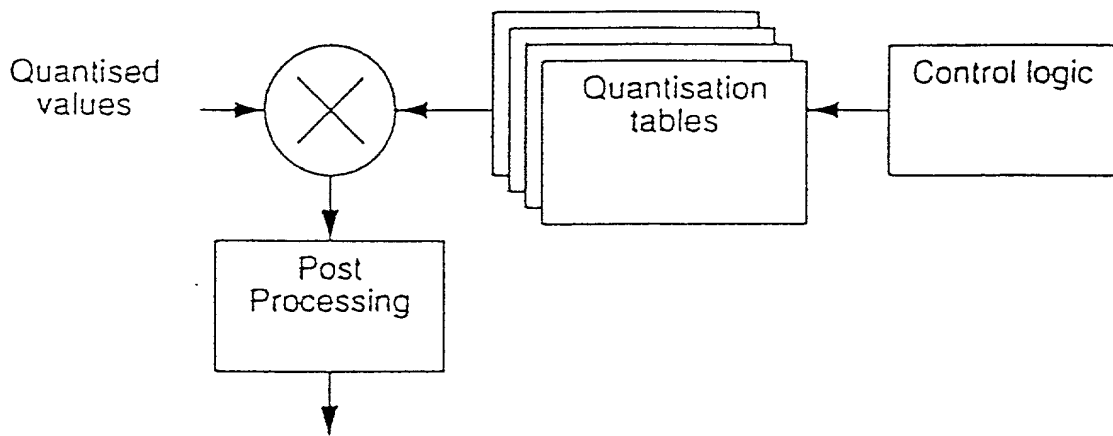


FIG.78

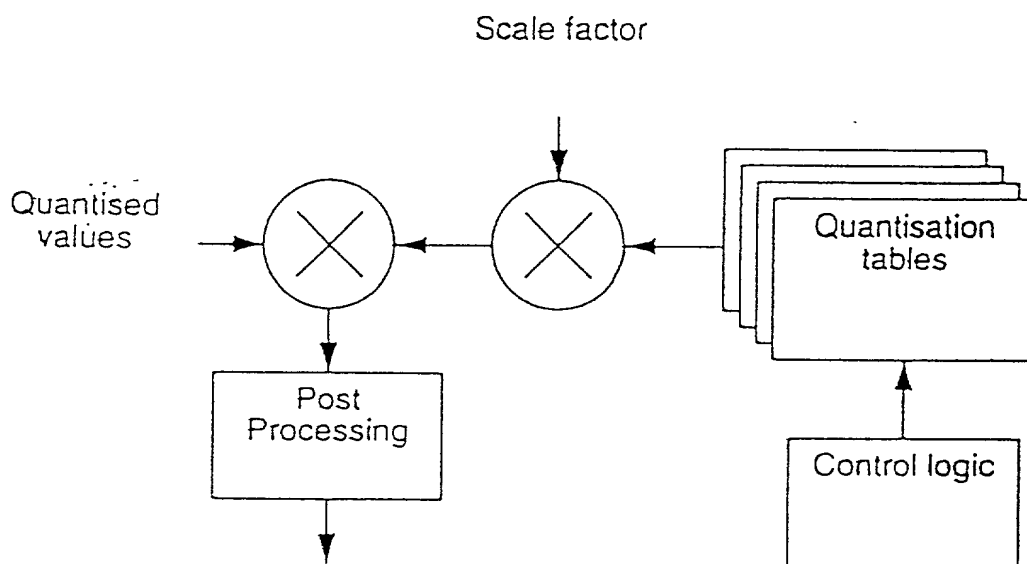


FIG.79

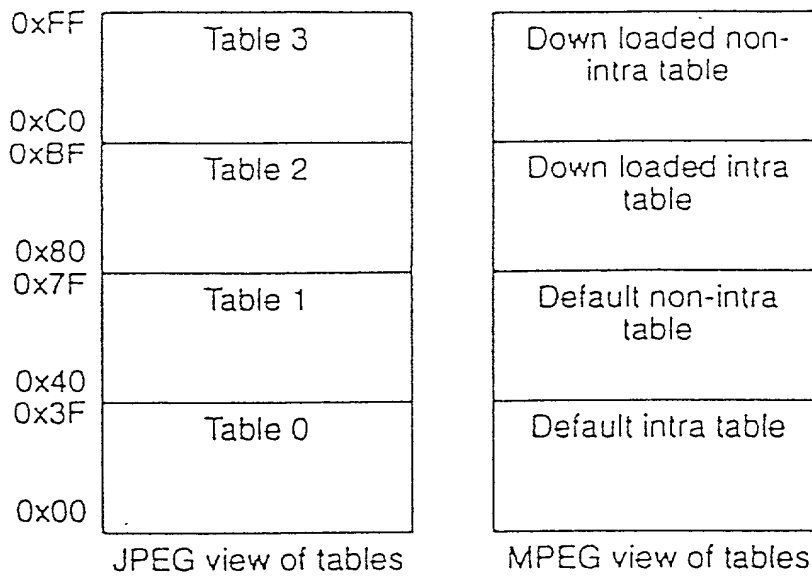


FIG.80

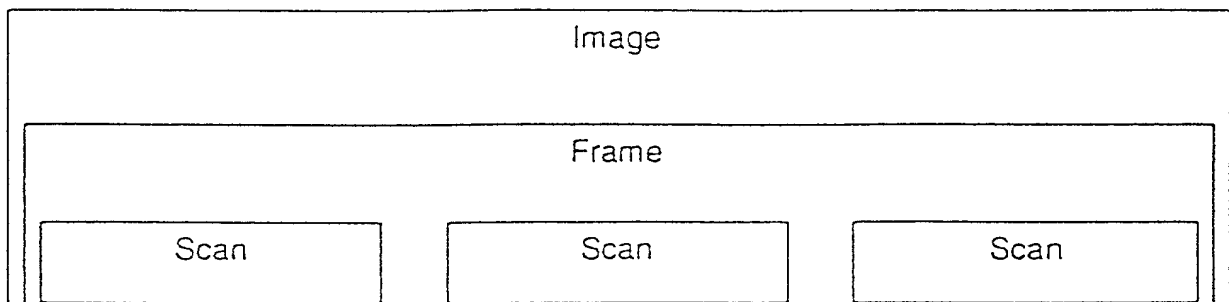


FIG.81

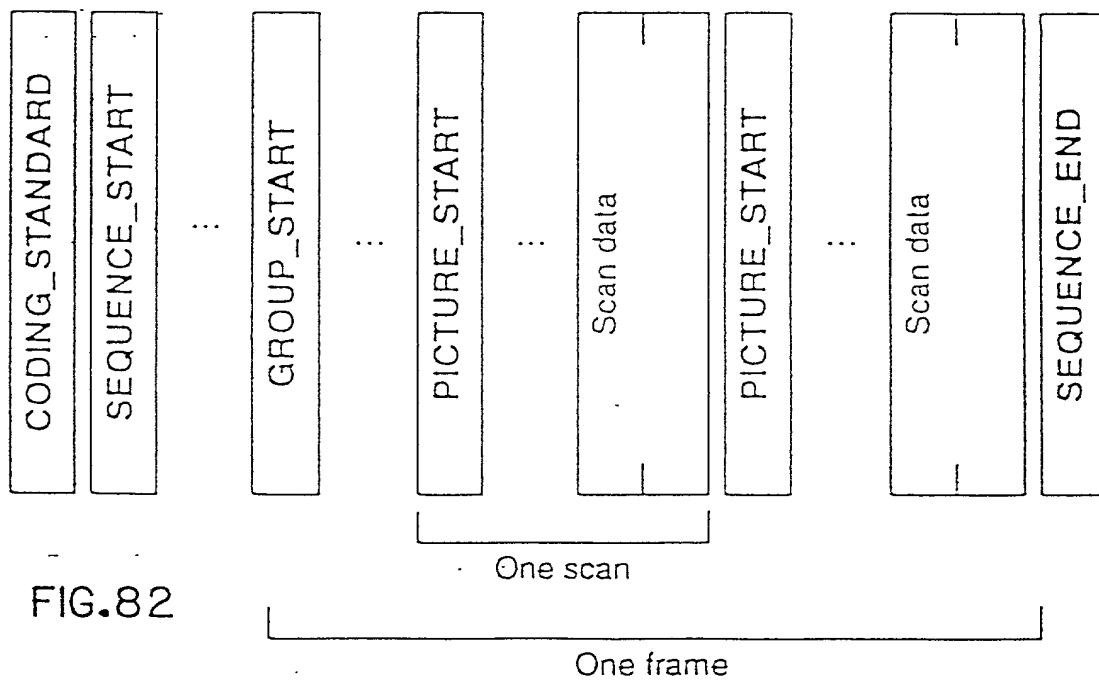


FIG.82

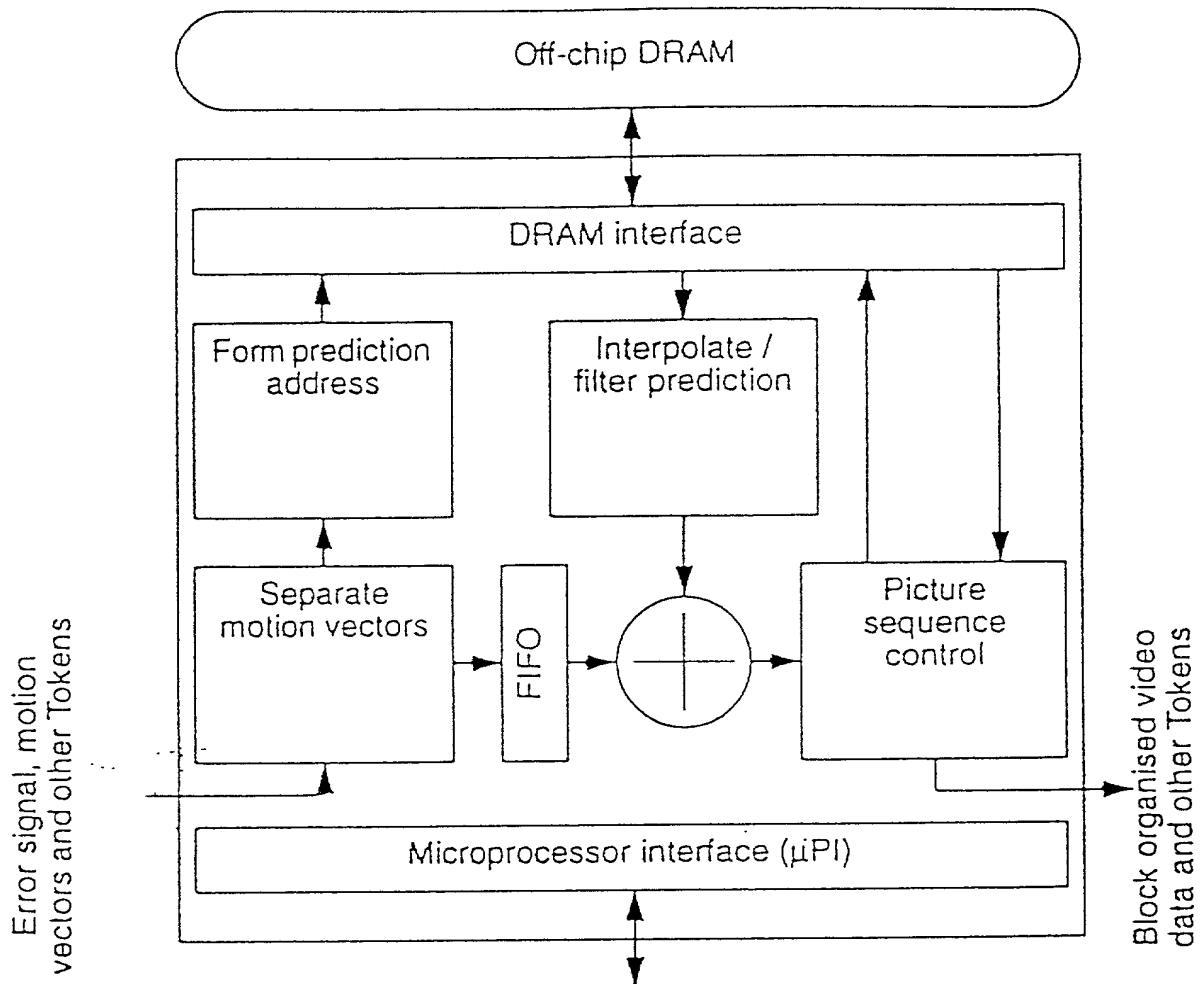


FIG.83

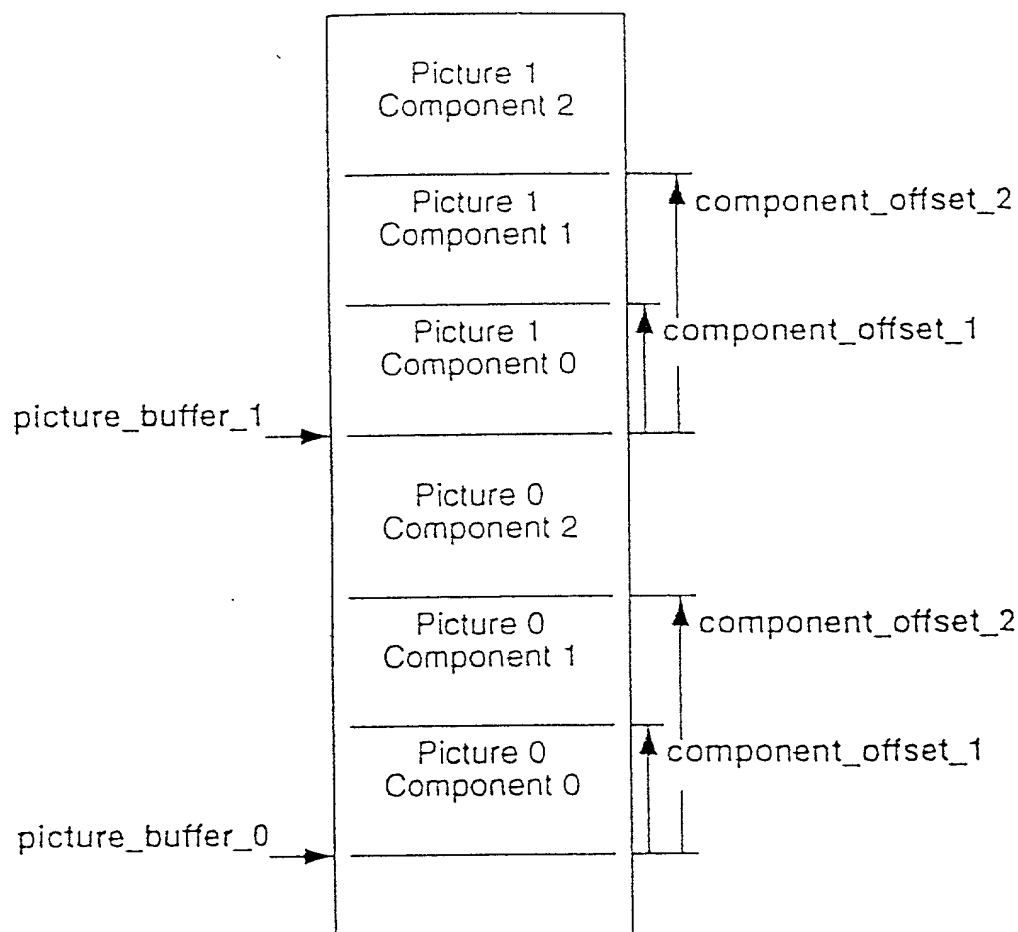


FIG.84

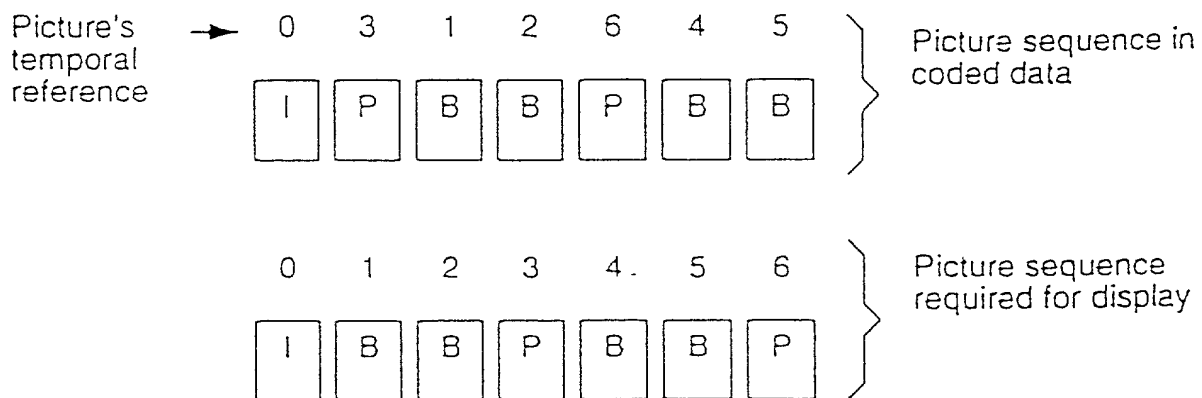


FIG.85

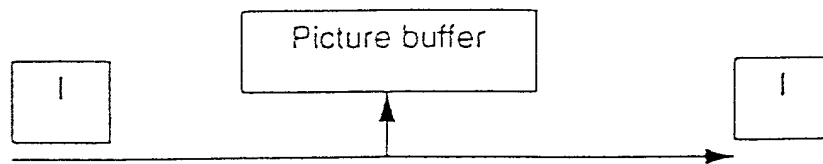


FIG.86

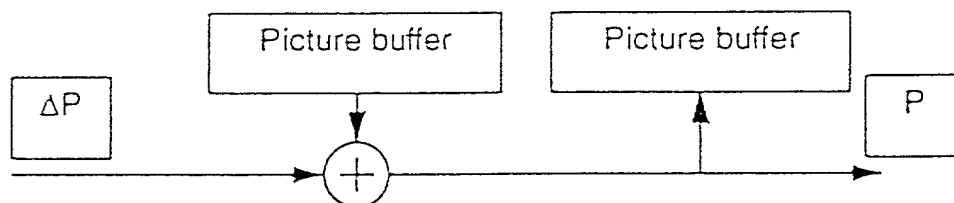


FIG.87

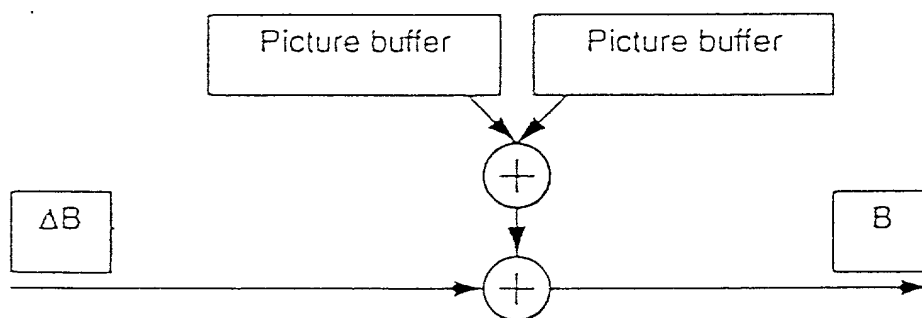


FIG.88

| Table 1. Demographic characteristics of the study population |                 |
|--------------------------------------------------------------|-----------------|
| Age (years)                                                  | 65.0 ± 1.5      |
| Gender (male/female)                                         | 10/10           |
| Education (years)                                            | 12.0 ± 1.0      |
| Occupation (years)                                           | 35.0 ± 2.0      |
| Marital status (married/divorced/widowed)                    | 10/0/0          |
| Income (USD/month)                                           | 1,200.0 ± 100.0 |
| Health status (good/fair/poor)                               | 10/0/0          |
| Smoking status (smoker/non-smoker)                           | 5/5             |
| Alcohol consumption (yes/no)                                 | 2/8             |
| Comorbidities (hypertension/diabetes/cholesterol)            | 5/5/5           |
| Medication (yes/no)                                          | 5/5             |
| Family history (yes/no)                                      | 5/5             |
| Stress level (low/moderate/high)                             | 5/5/0           |
| Sleep quality (good/fair/poor)                               | 10/0/0          |
| Physical activity (yes/no)                                   | 5/5             |
| Dietary habits (healthy/unhealthy)                           | 5/5             |
| Overall health score (1-10)                                  | 7.5 ± 1.0       |

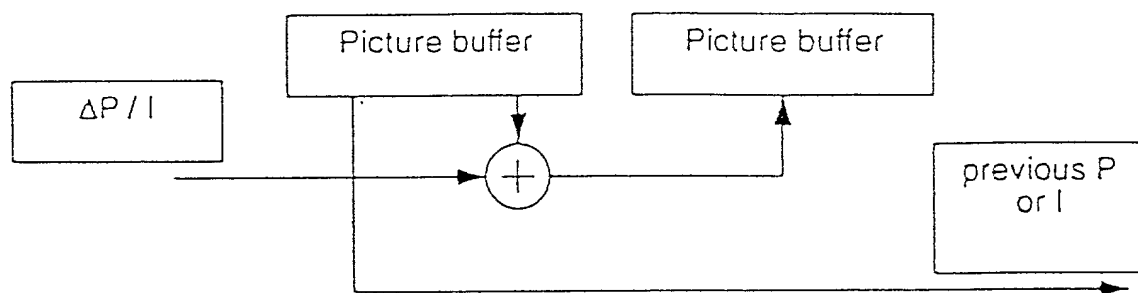


FIG. 89

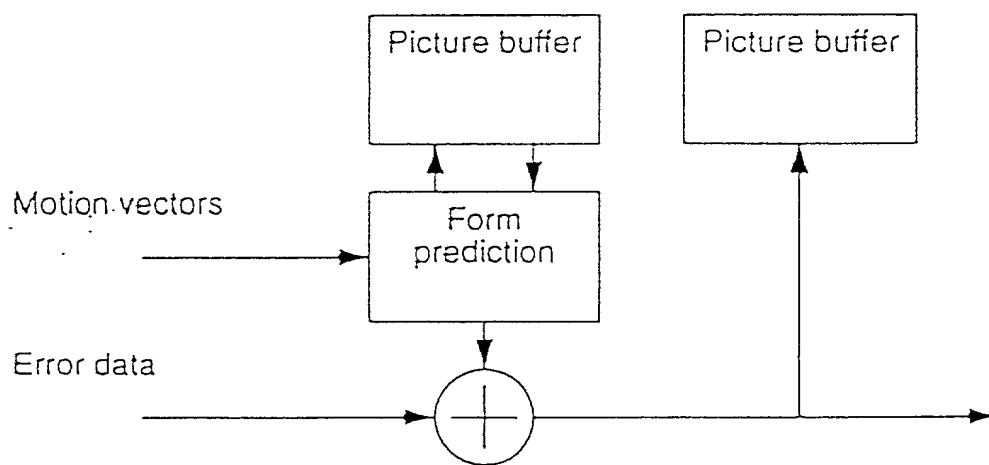


FIG.90

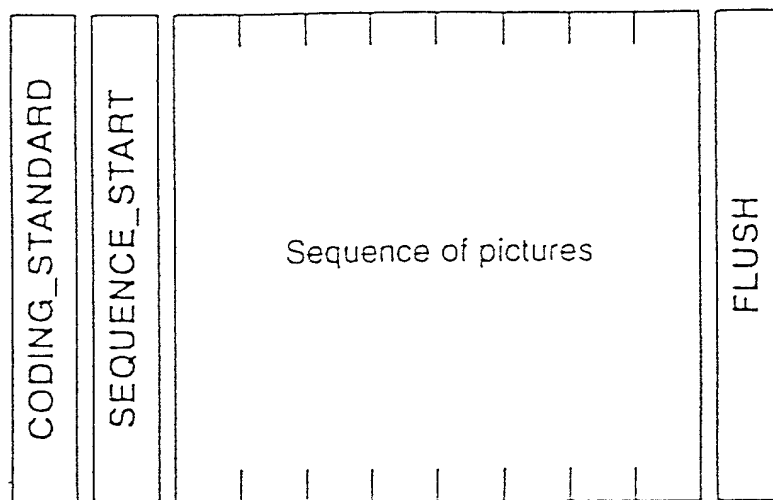


FIG.91

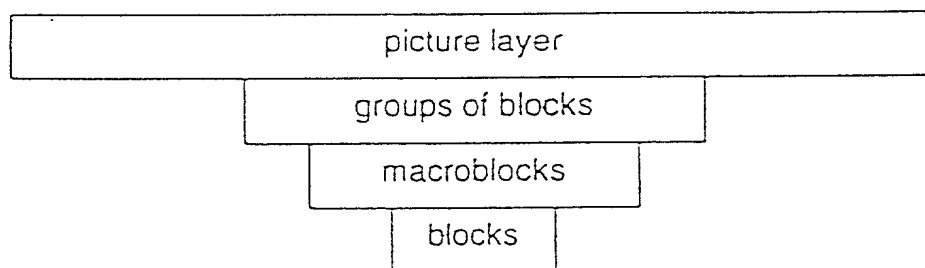


FIG.92



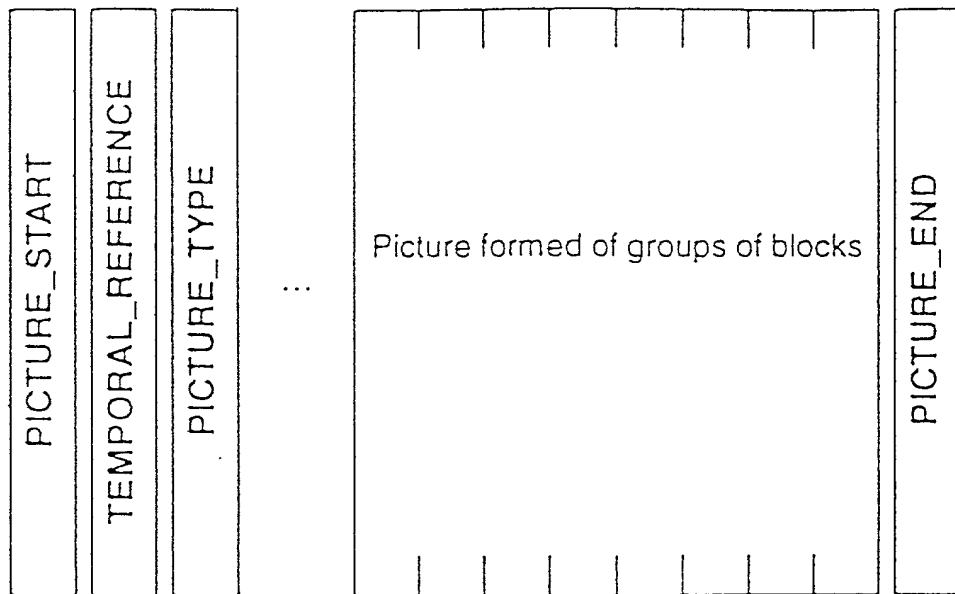


FIG.93

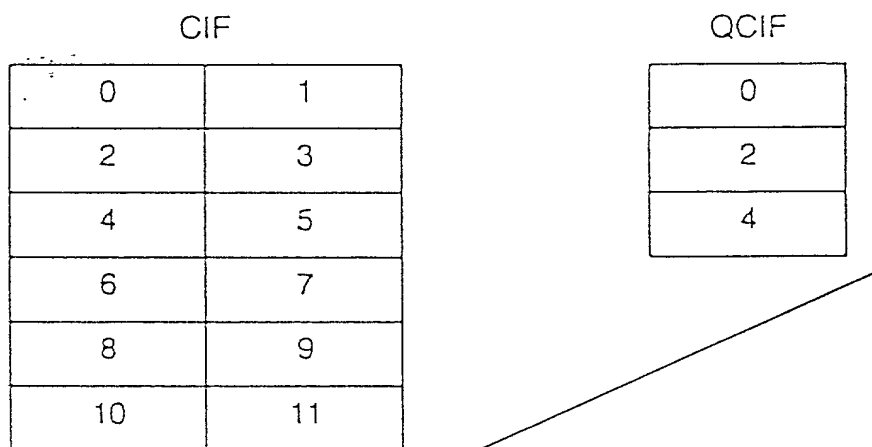


FIG.94



|    |    |    |    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |

FIG.96

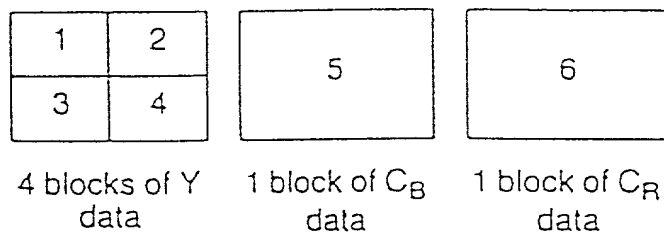


FIG.97

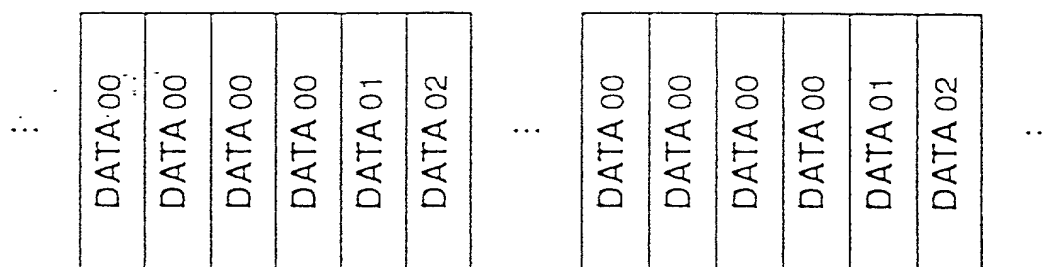


FIG.98

|   |    |    |    |    |    |    |    |
|---|----|----|----|----|----|----|----|
| 1 | 2  | 3  | 4  | 5  | 6  | 7  | 8  |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |

⋮

|    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|
| 59 | 58 | 59 | 60 | 61 | 62 | 63 | 64 |
|----|----|----|----|----|----|----|----|

FIG.99

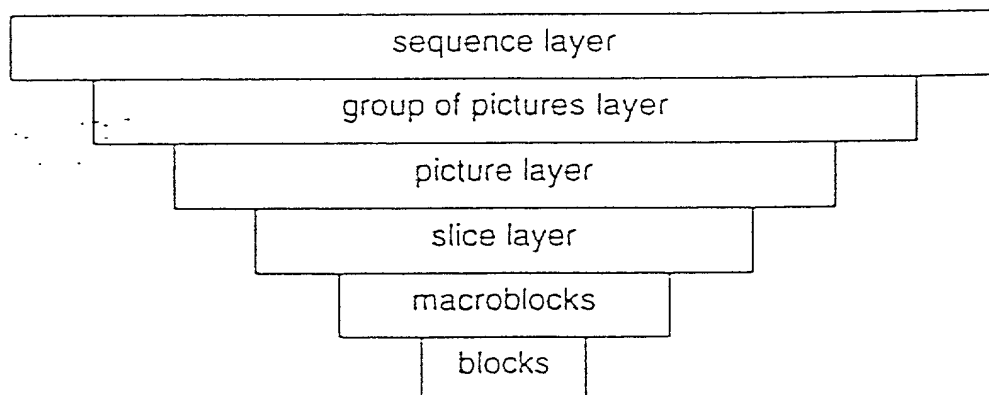


FIG.100

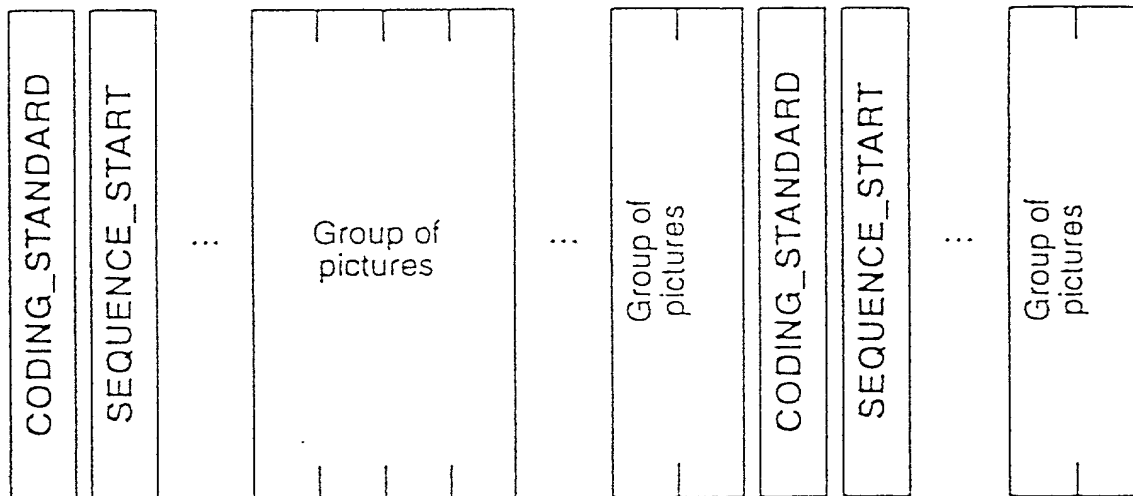


FIG. 101

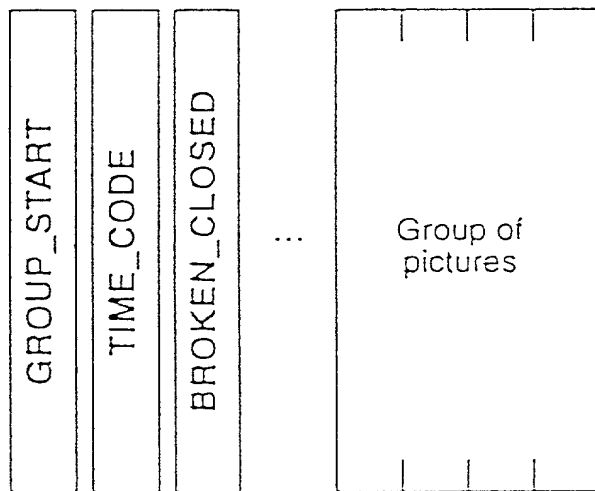


FIG. 102

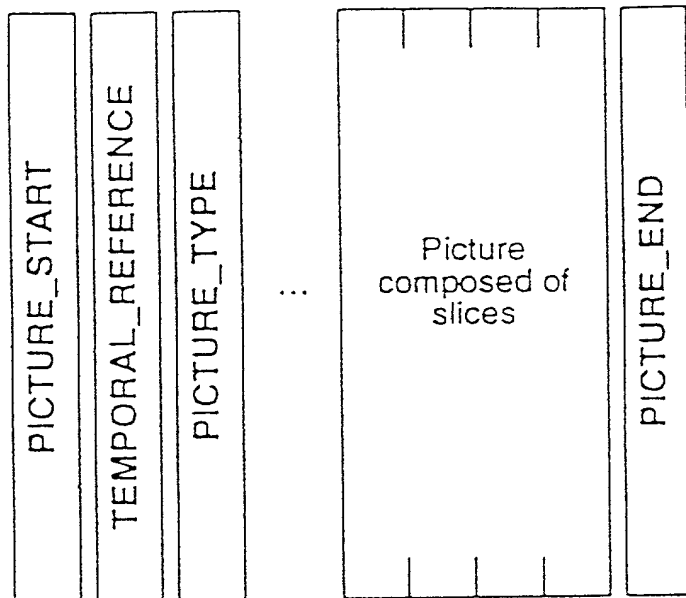


FIG. 103

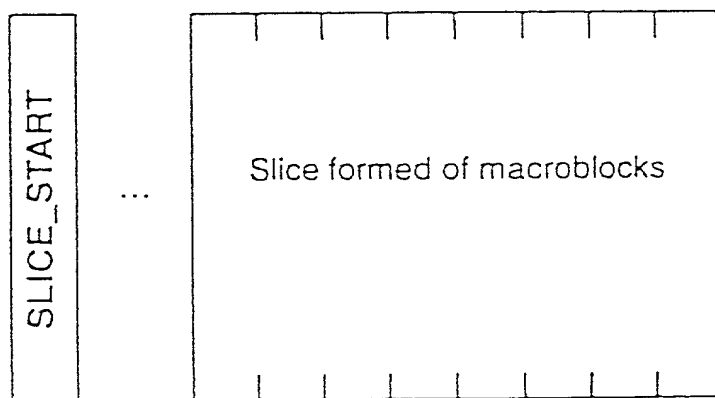


FIG. 104



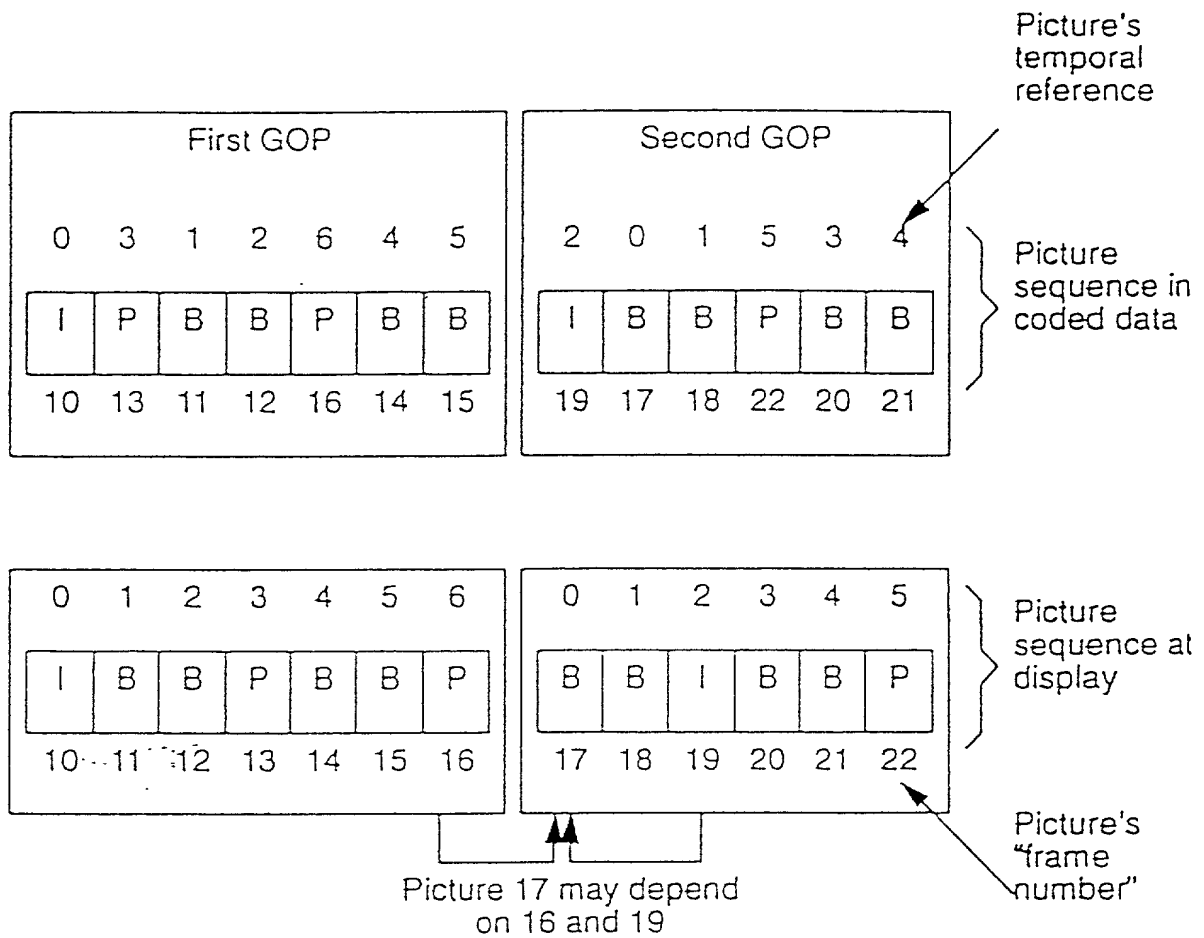


FIG. 107





RAS

```
DRAM_addr[10:0]
```

CAS[3:0]

WE

CE

```
DRAM_data[31:0]
```

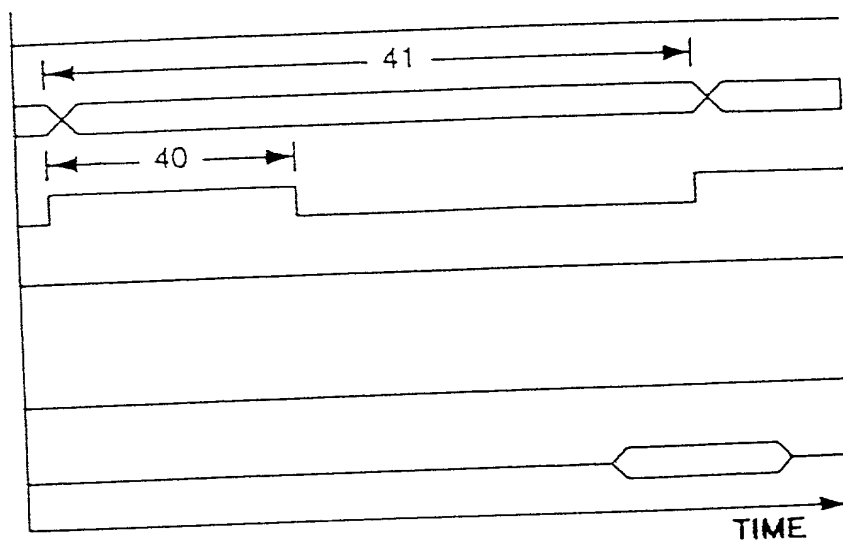


FIG. 110

RAS

DRAM\_addr[10:0]

 $\overline{\text{CAS}}[3:0]$ 

WE

 $\overline{OE}$ 

```
DRAM_data[31:0]
```

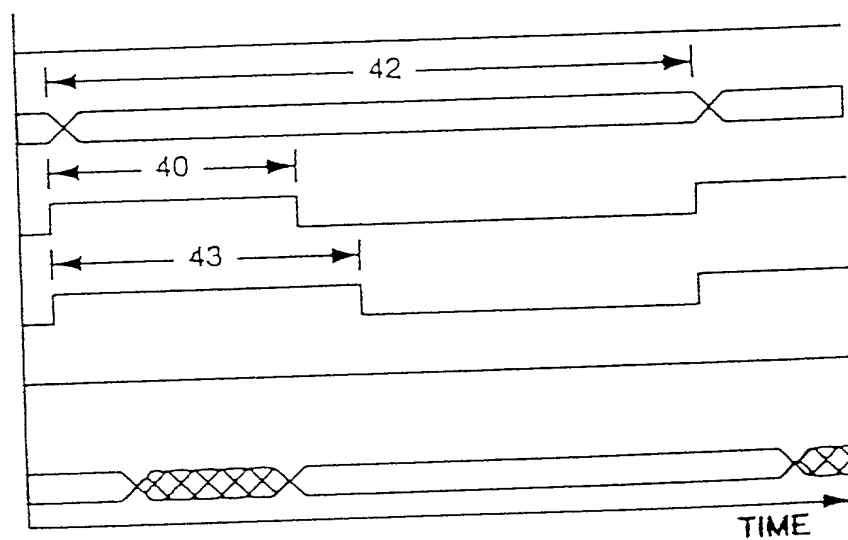


FIG. 1-111

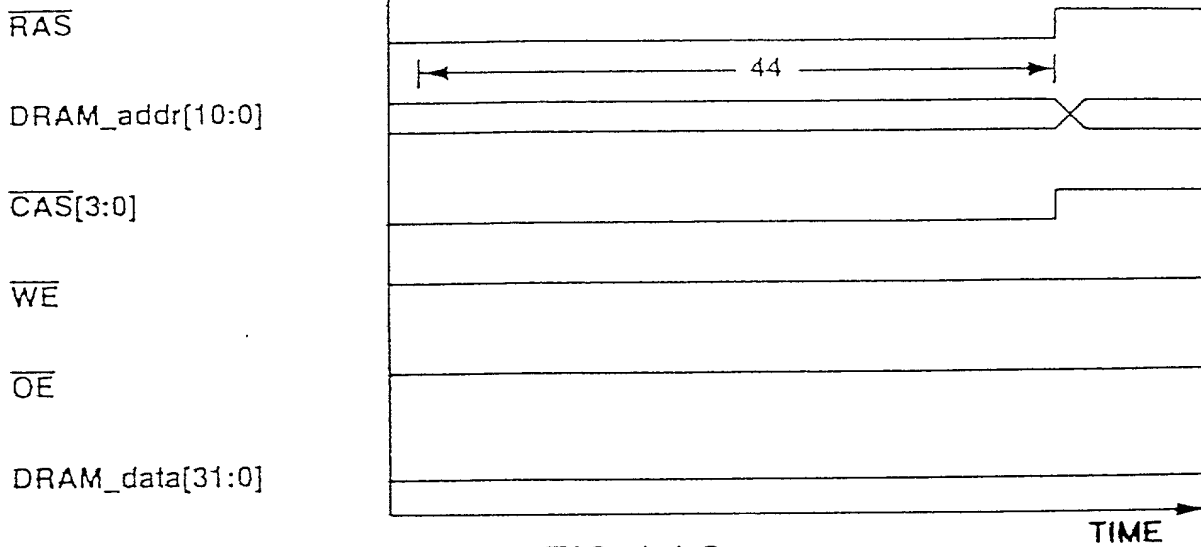


FIG. 112

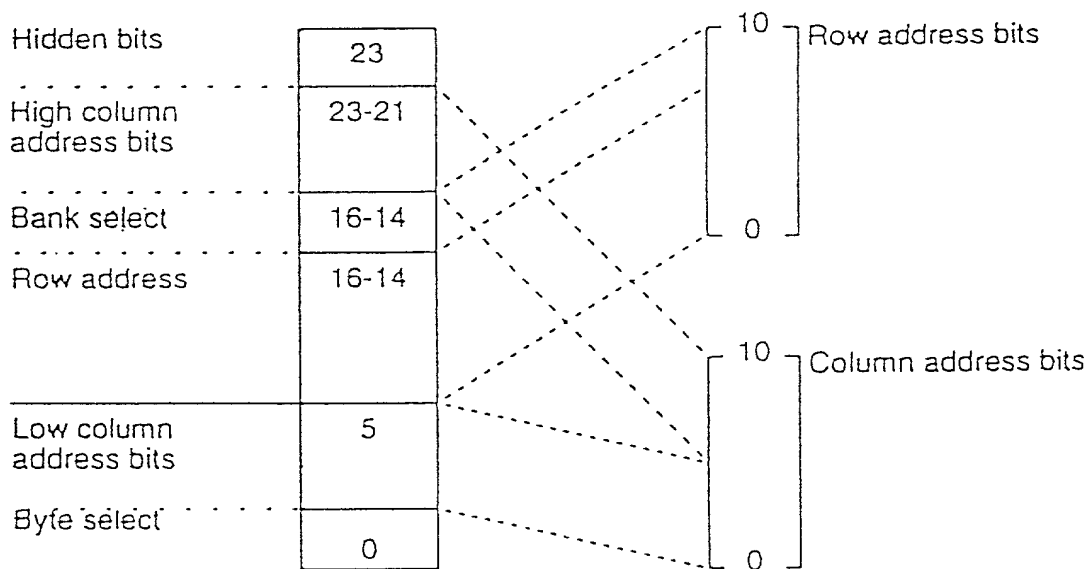


FIG. 113

Any signal

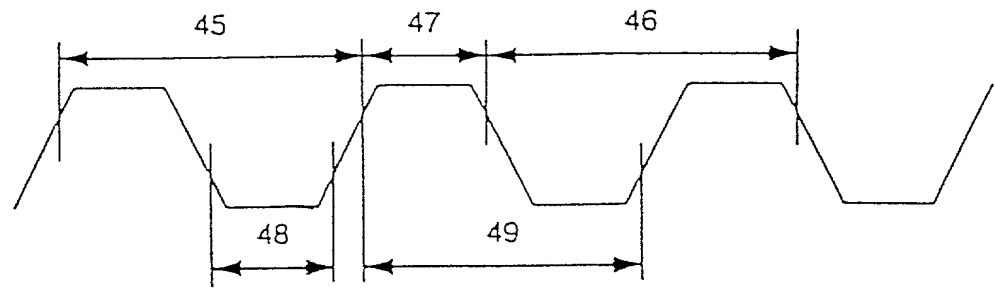


FIG. 114

Any signal

Any other  
signal

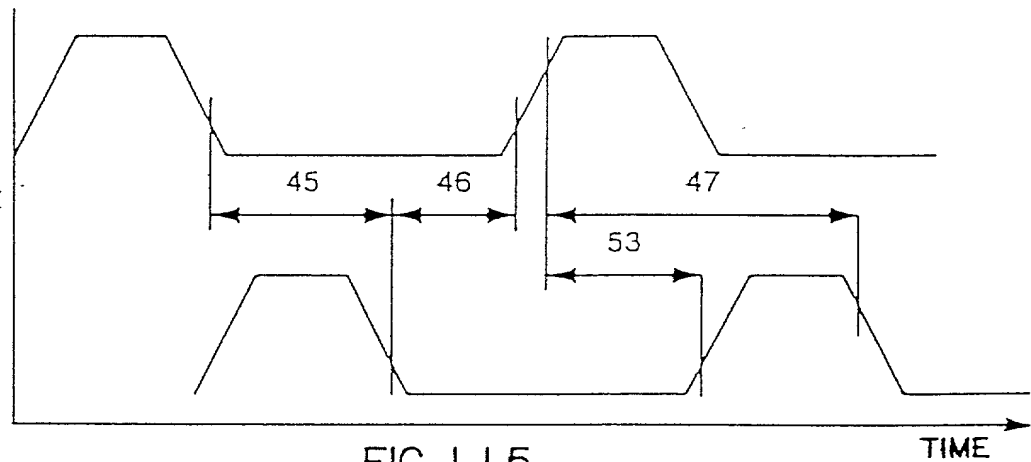
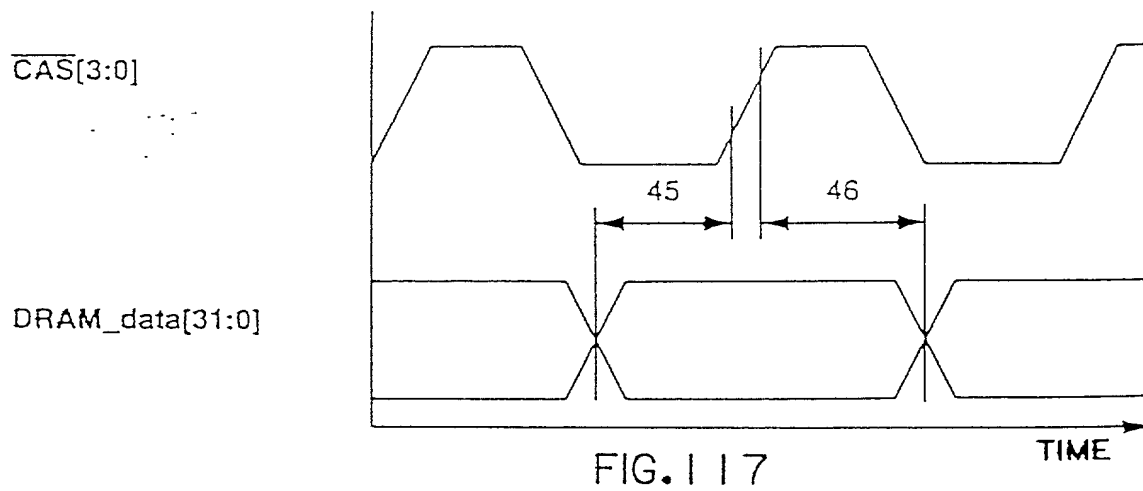
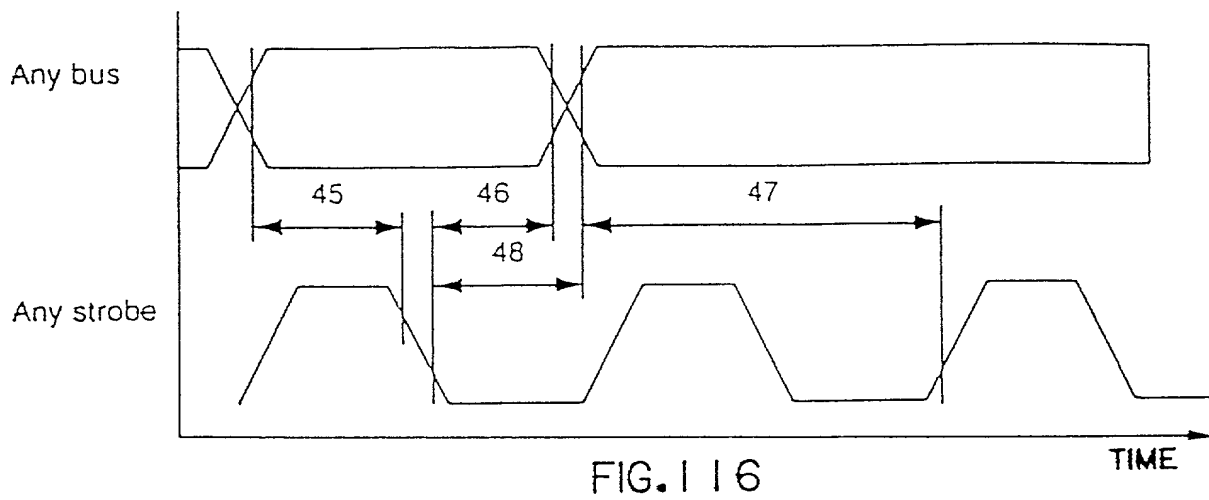
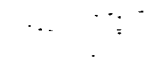


FIG. 115





002401 0216550

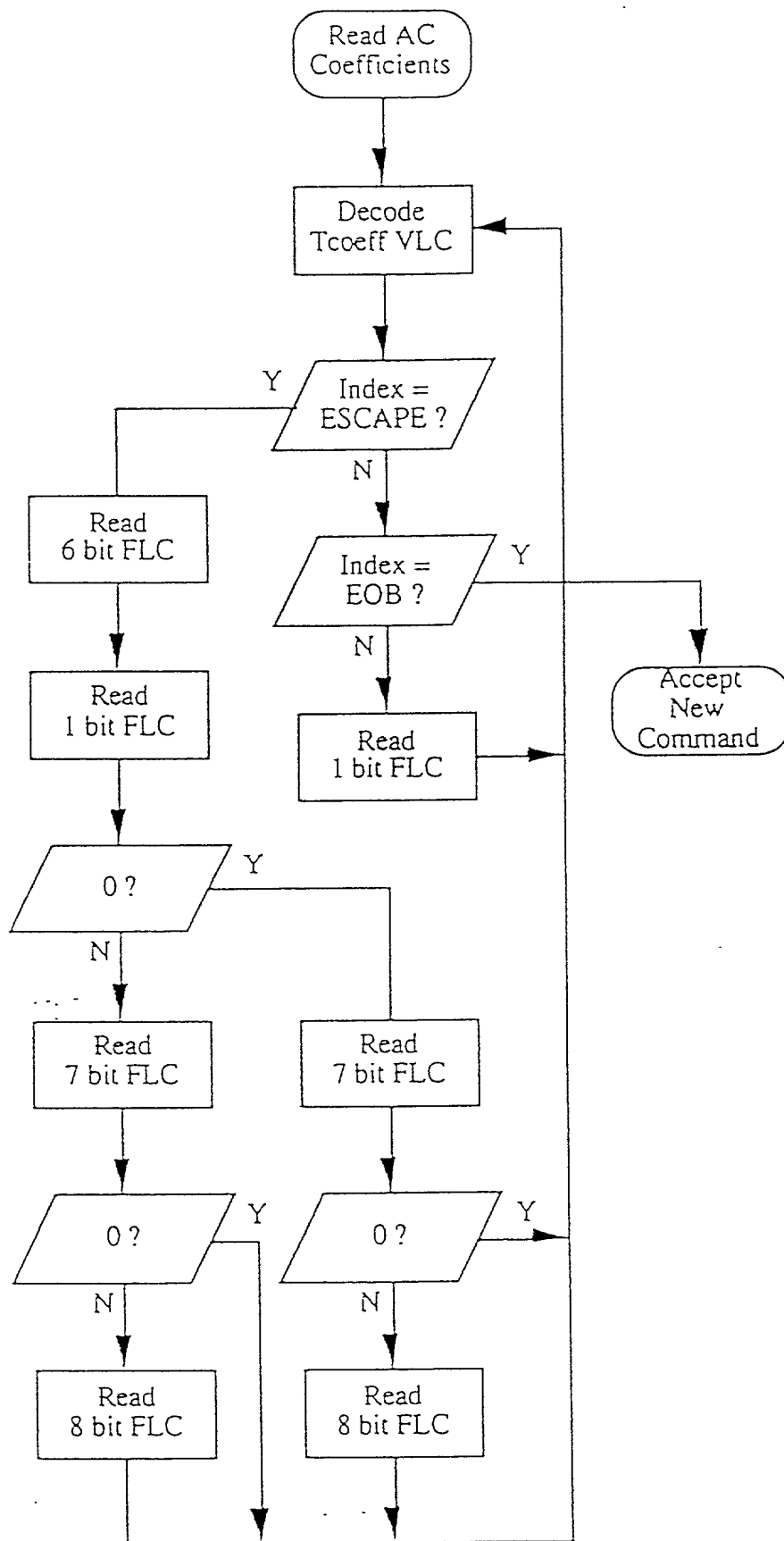


FIG. 119

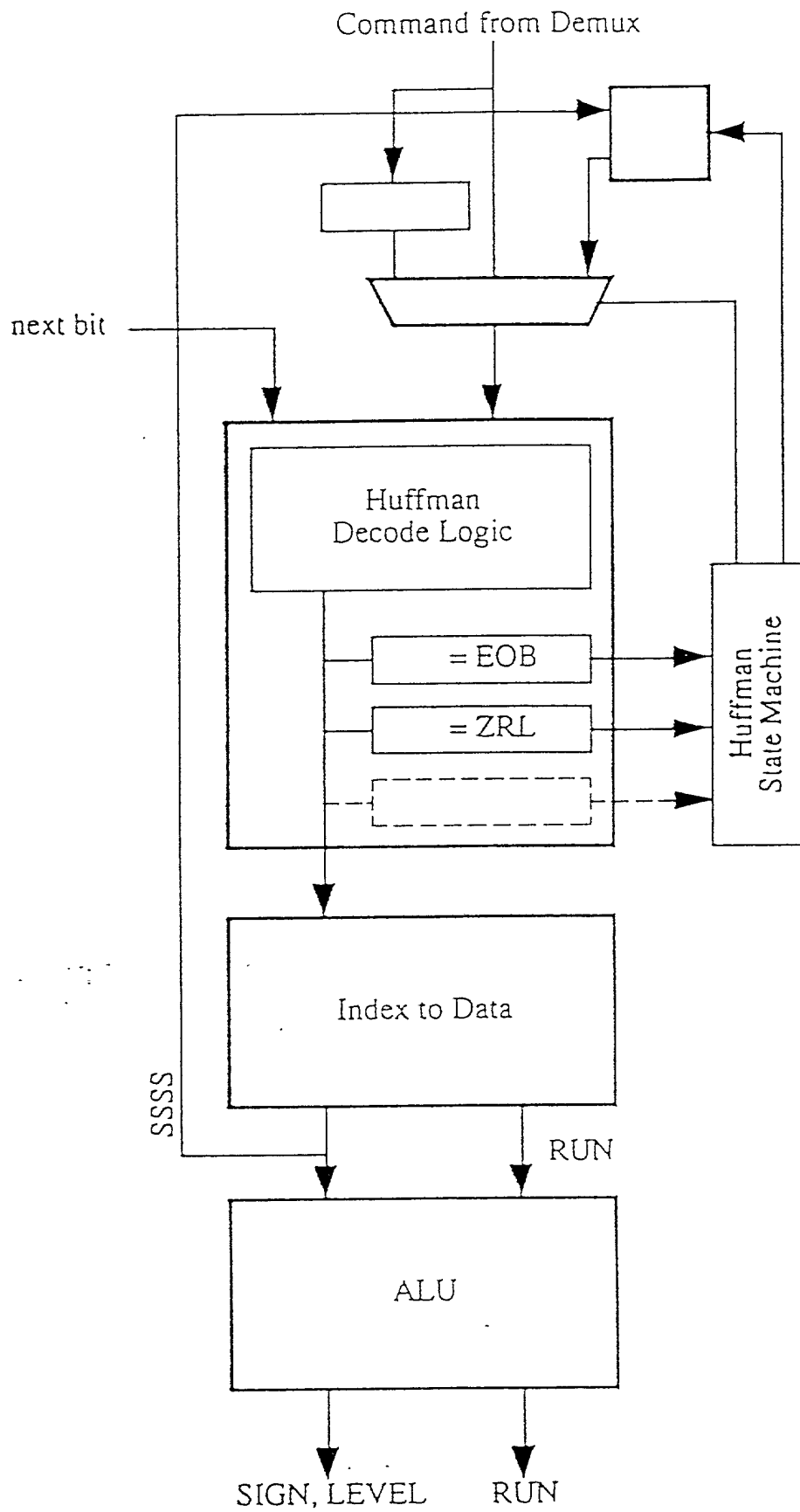


FIG. 120



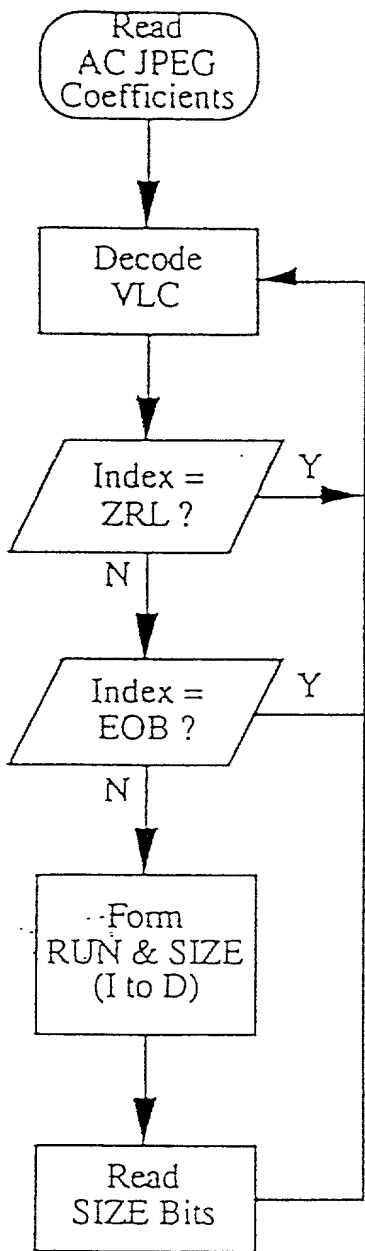


FIG. 121A

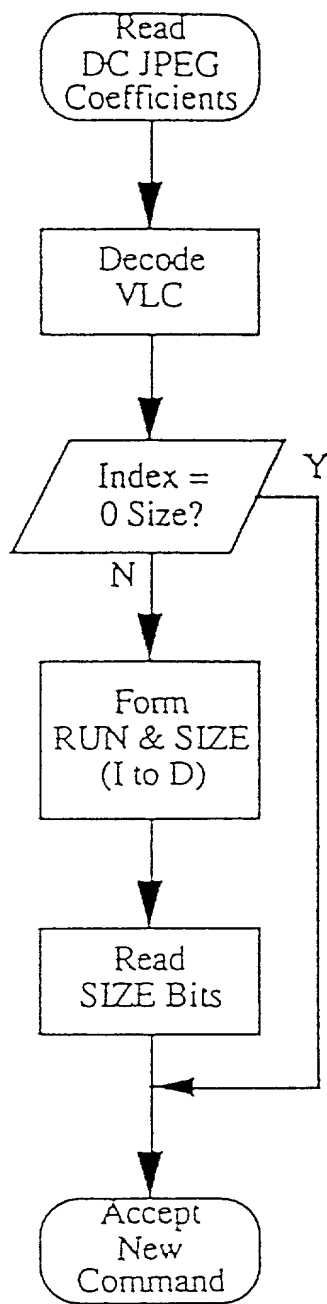


FIG. 121B

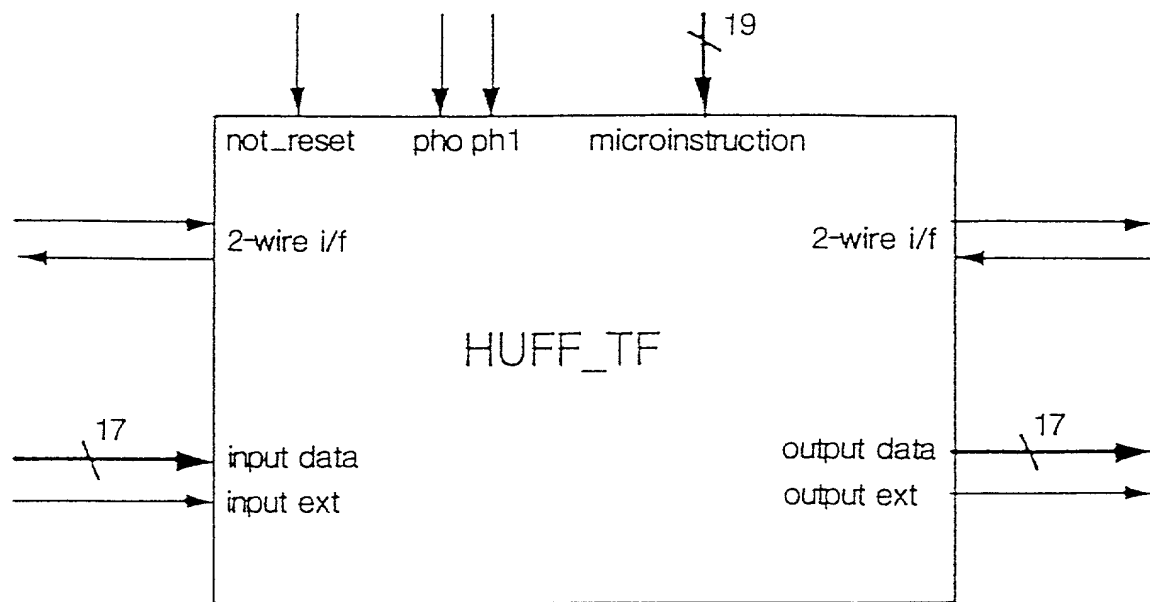


FIG. 122

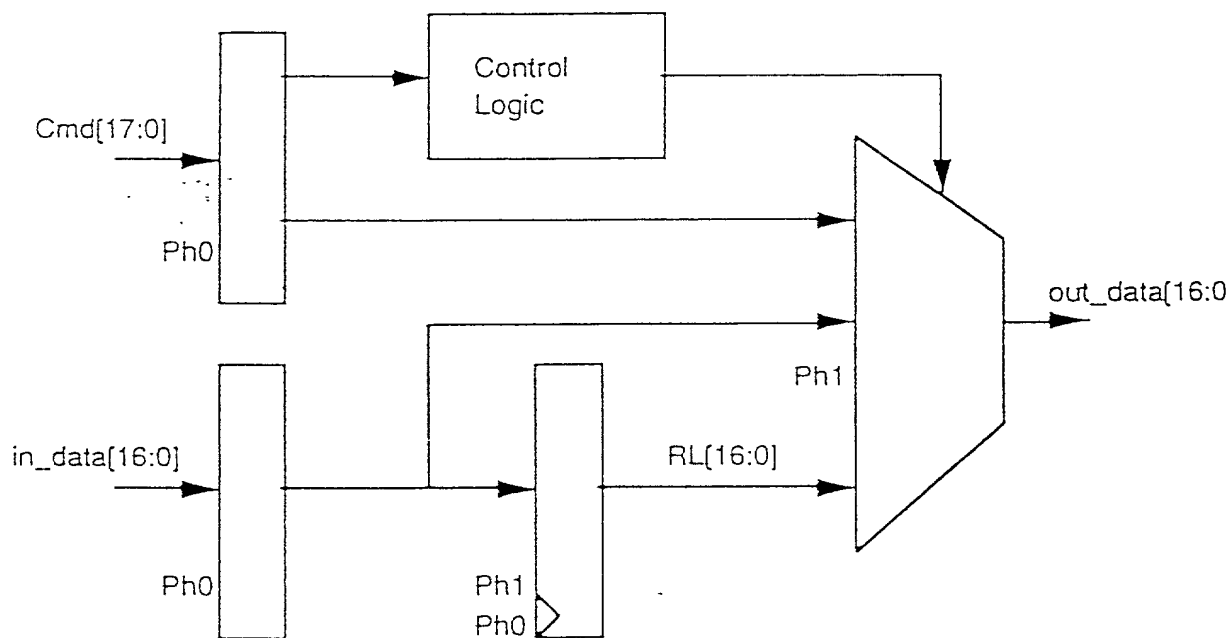


FIG. 123

002201 02158960

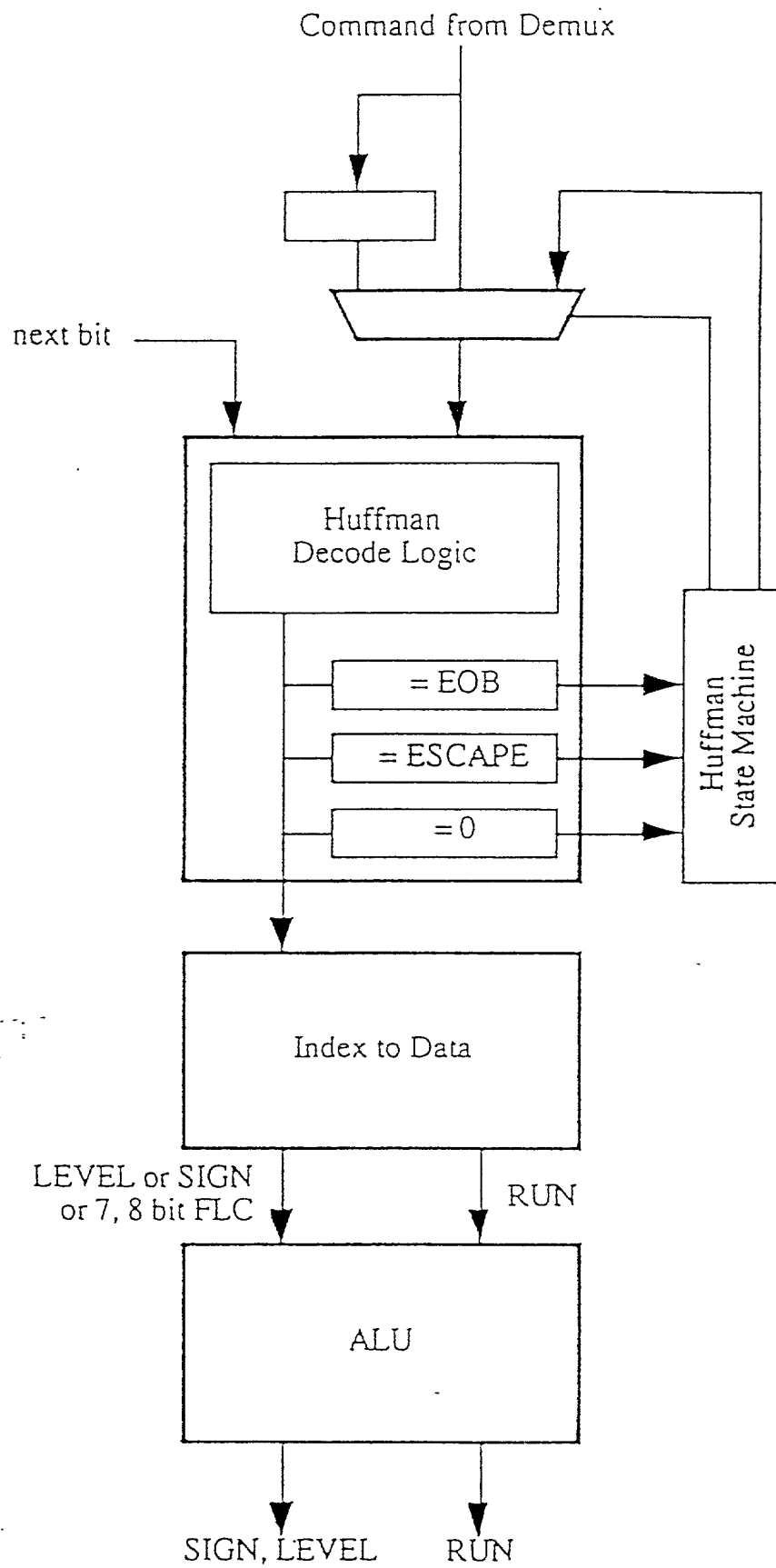


FIG. 124

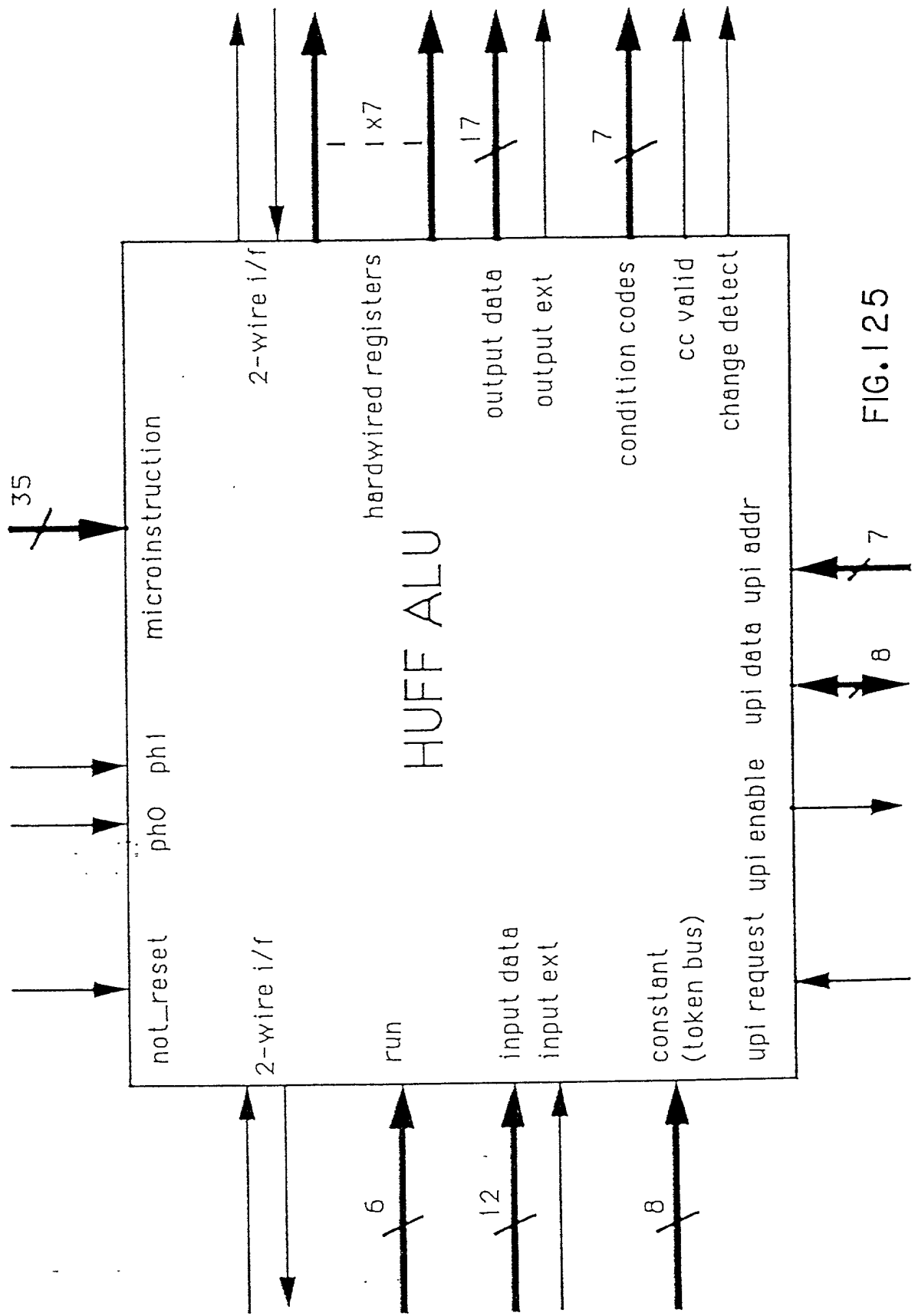


FIG. 125

0669120 10360

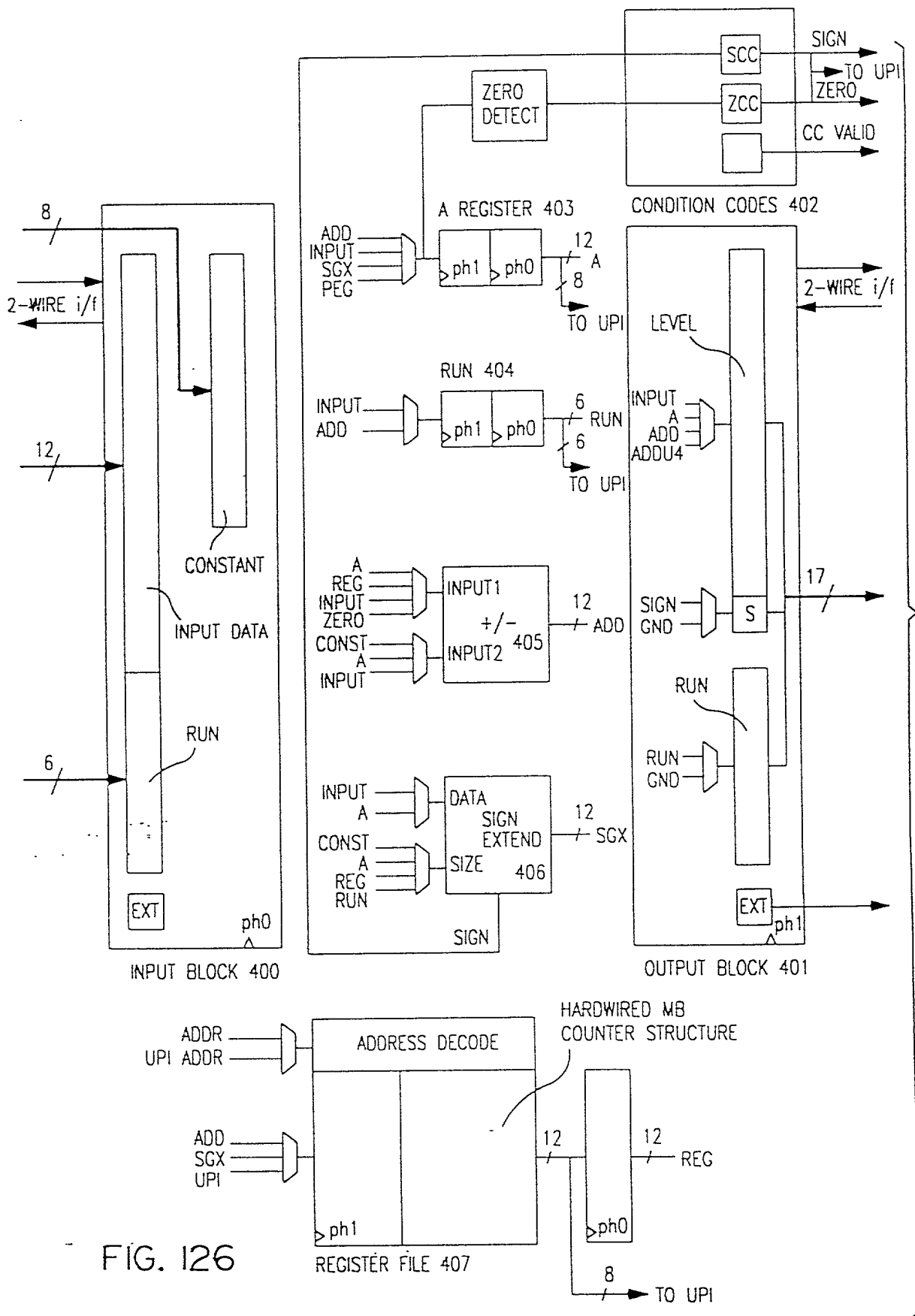


FIG. 126

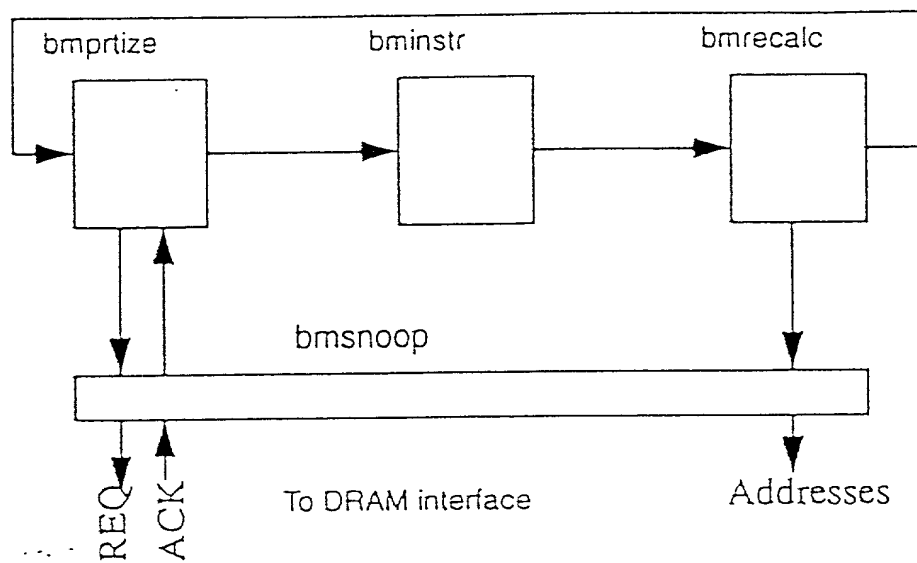


FIG. 127

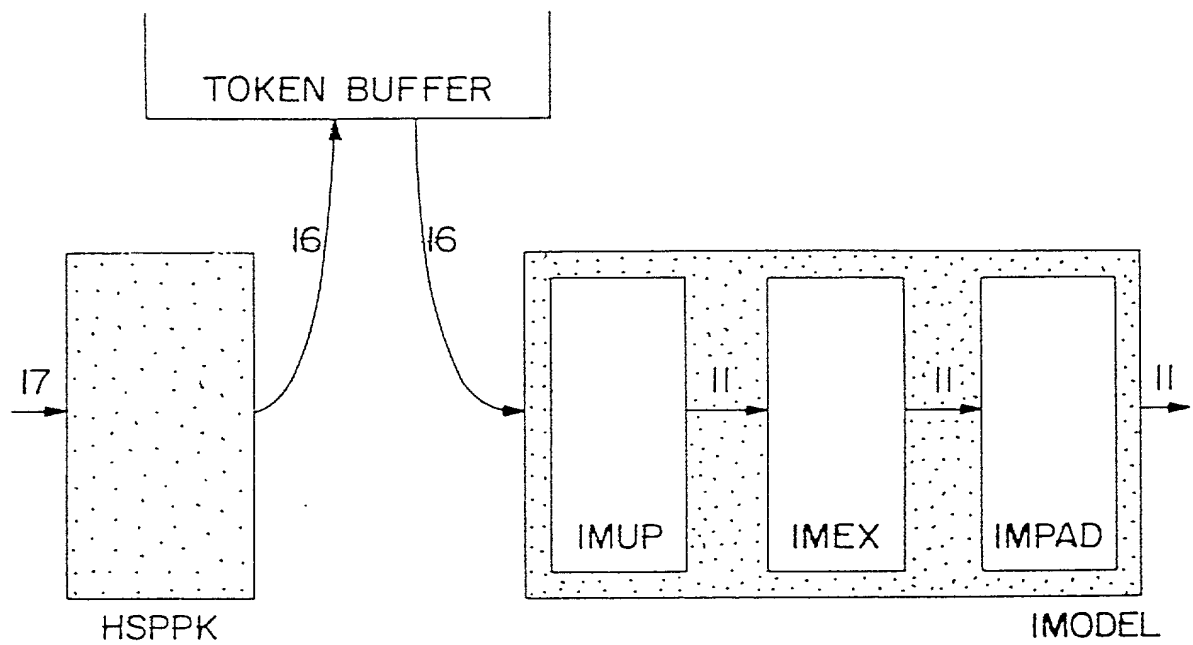


FIG. 128

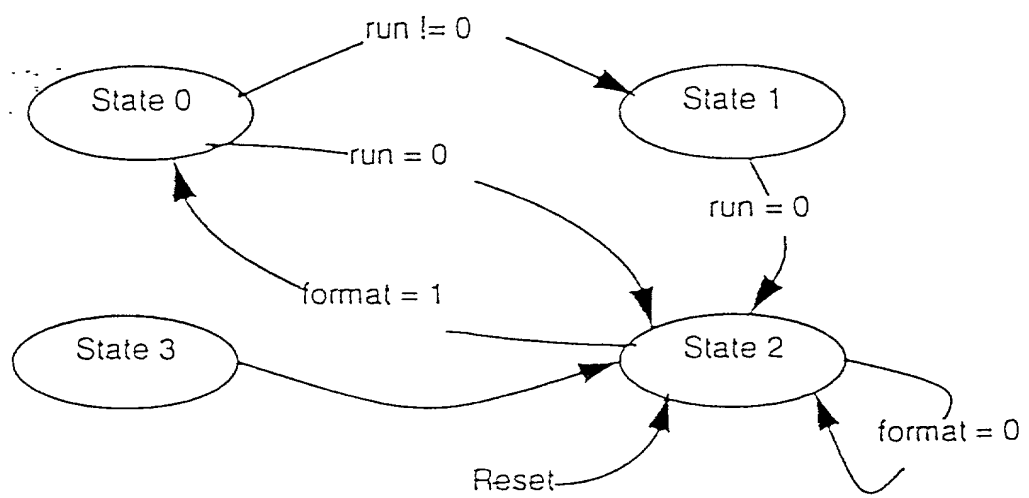


FIG. 129

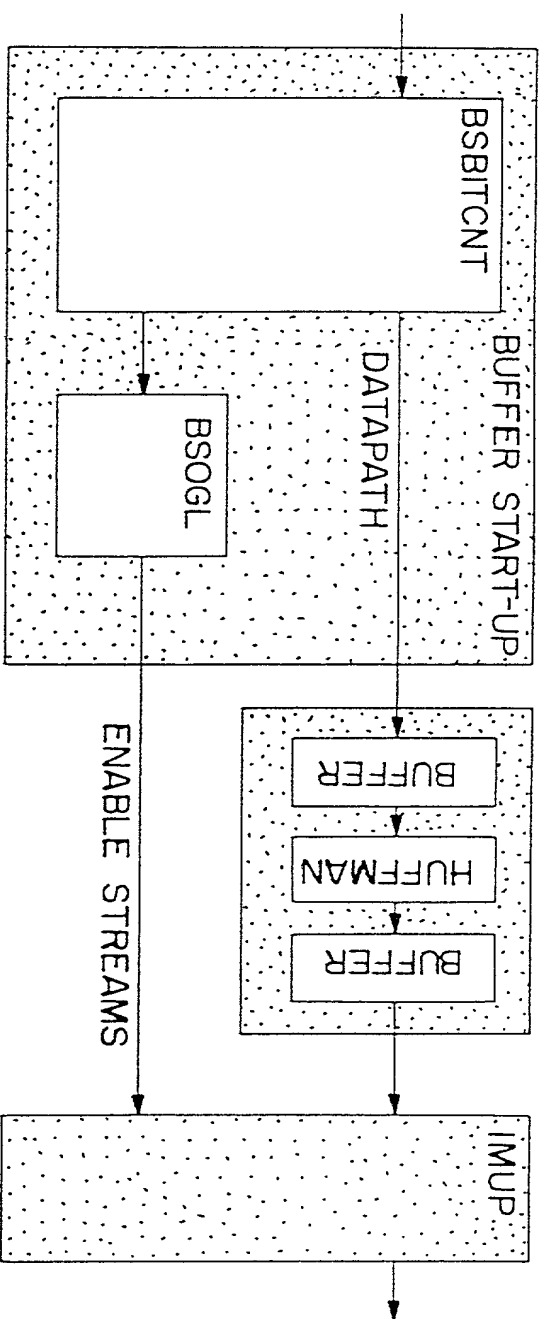


FIG. 130



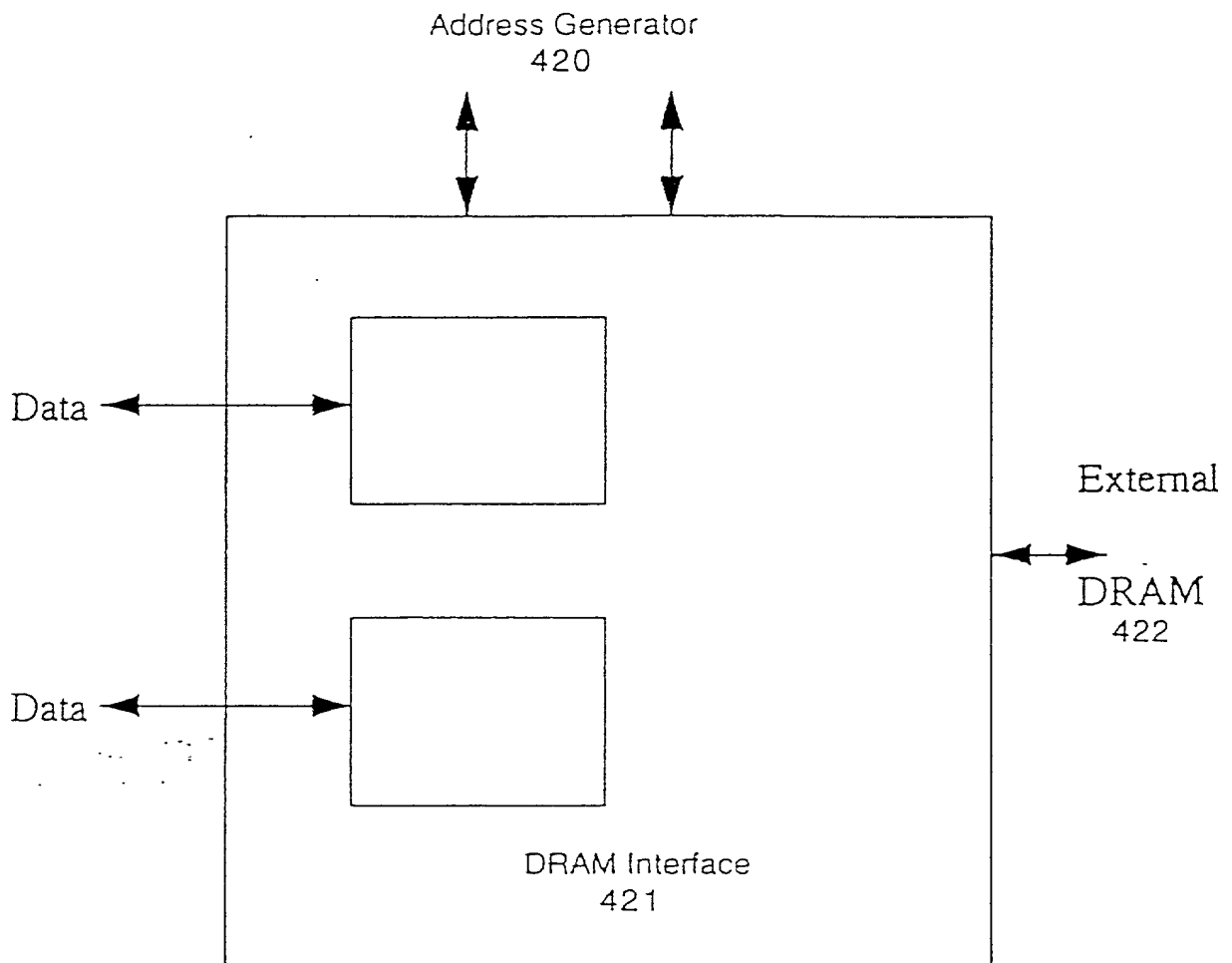


FIG. 131

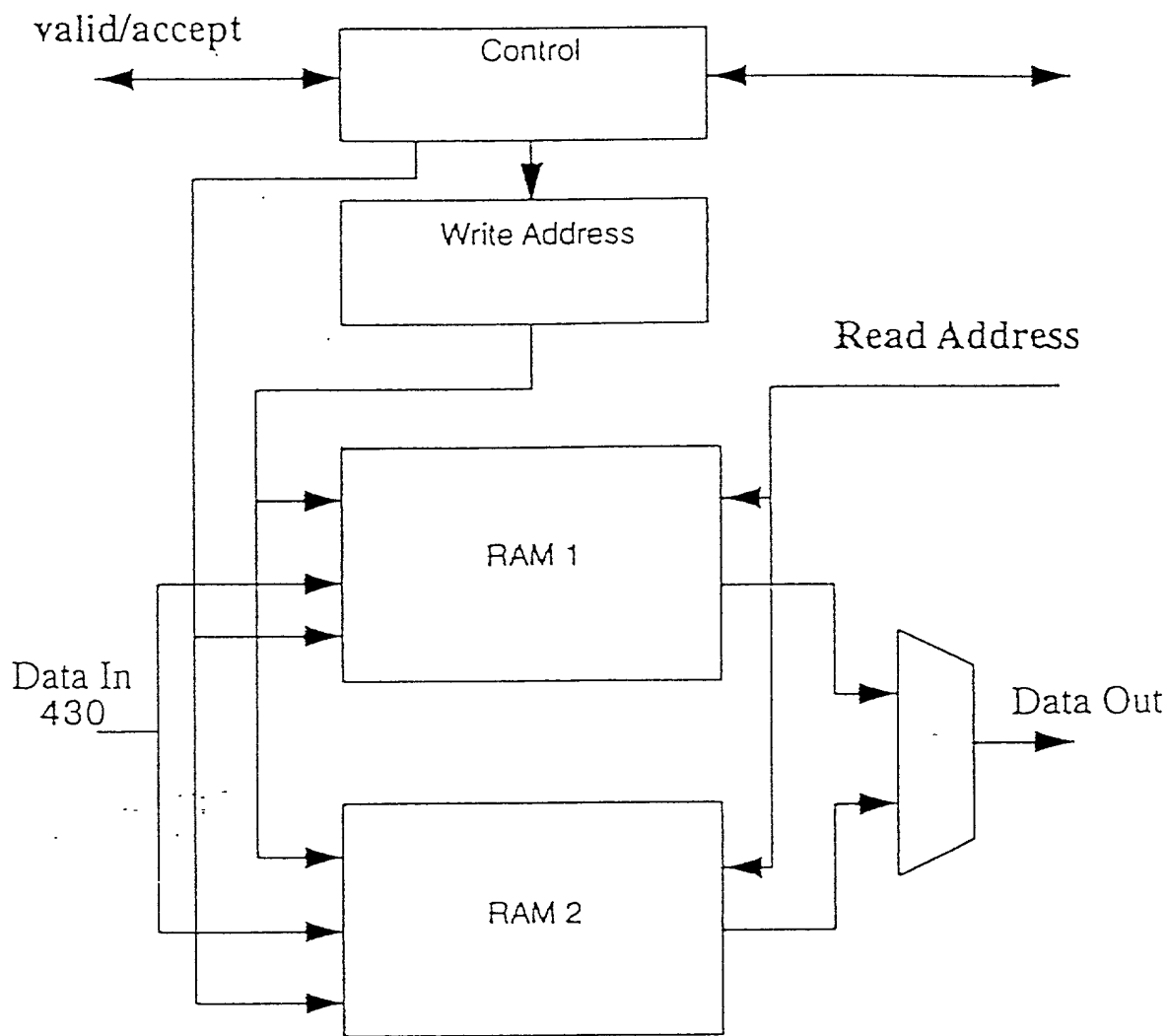


FIG. 132

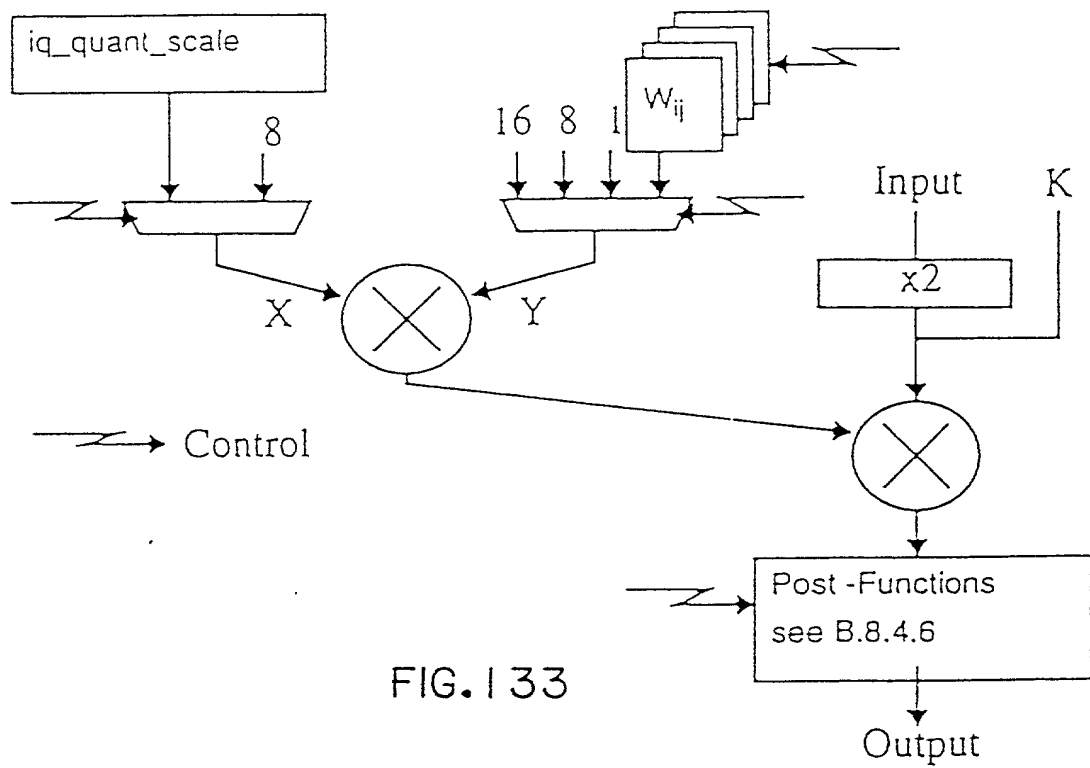


FIG. 133

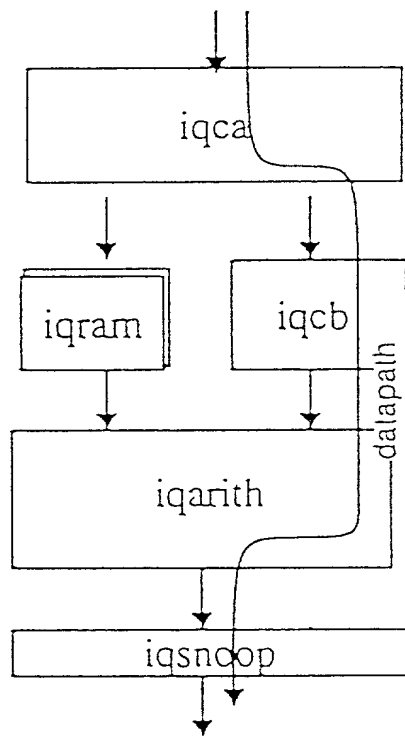


FIG. 134

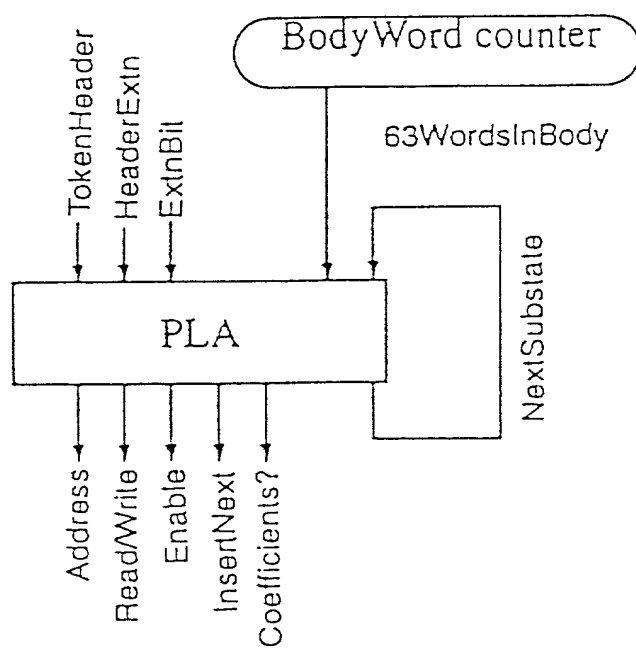


FIG. 135

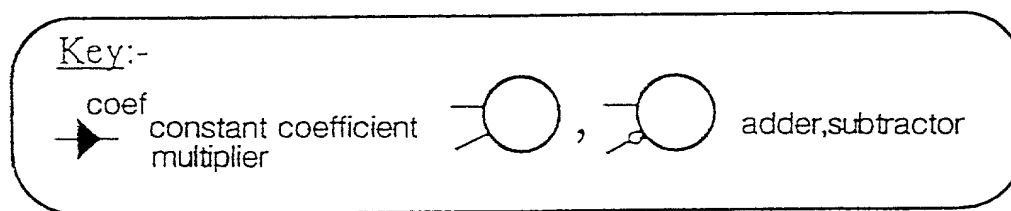


FIG. 136

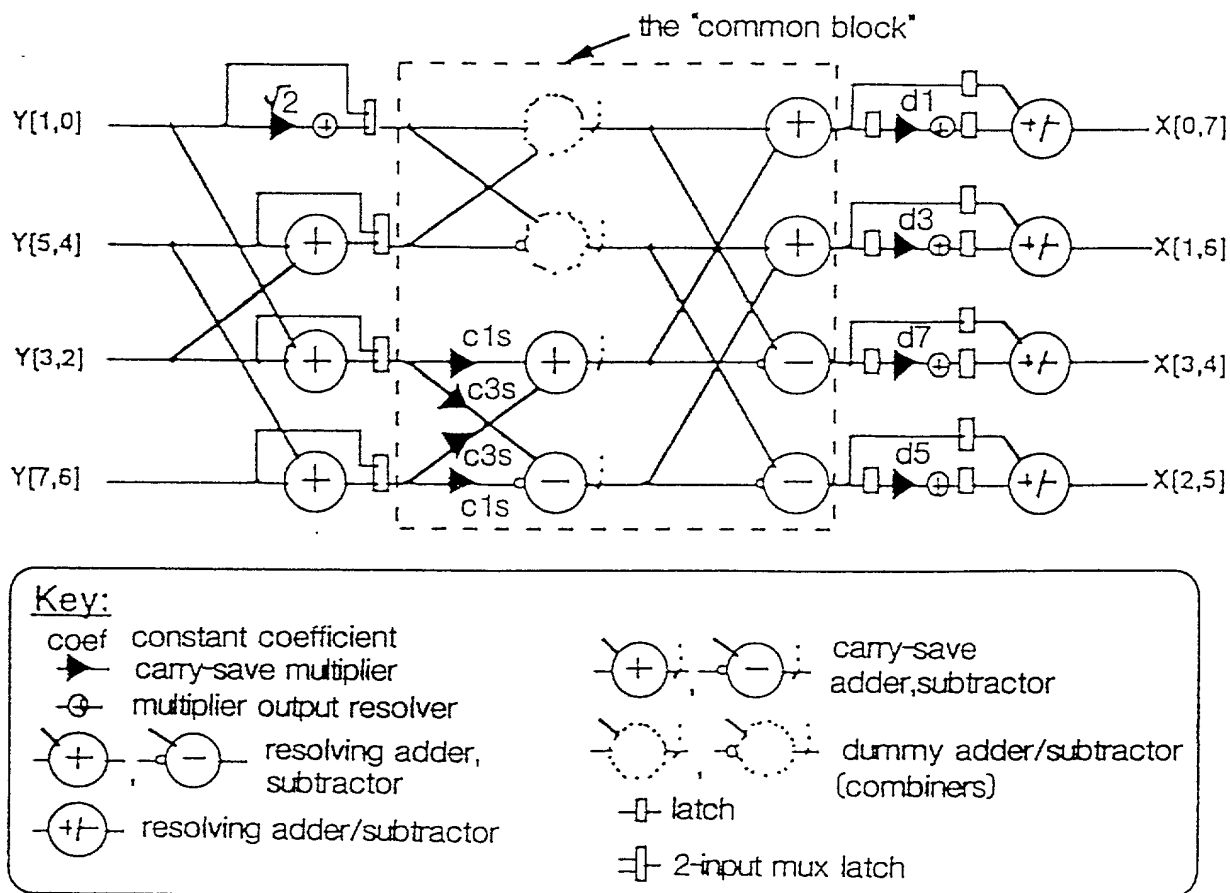


FIG. 137

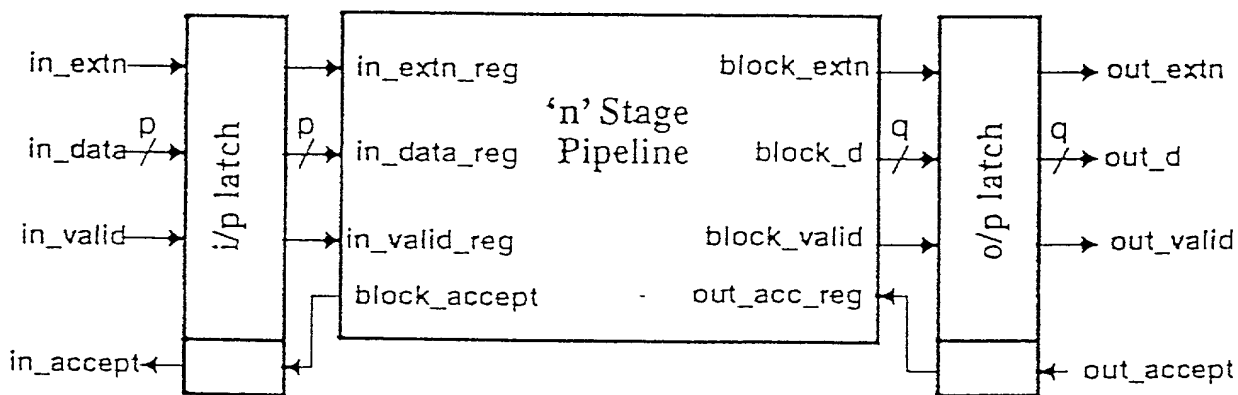


FIG. 138

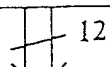
12

12 bit integer

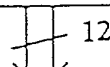
```

graph TD
    430[decheck  
DATA Error Checking and  
Recovery] --> 440[440]

```



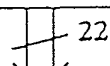
izz  
Inverse Zig-Zag RAM 441



```

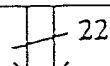
graph LR
    440[440] --> 441[441]
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    650 --> 651[651]
    651 --> 652[652]
    652 --> 653[653]
    653 --> 654[654]
    654 --> 655[655]

```



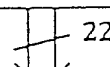
10 bits fraction

oned  
1-D IDCT Transform

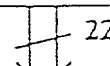


7 bits fraction

tram  
Inverse Zig-Zag RAM

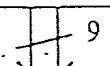


oned  
1-D IDCT Transform



4 bits fraction

ras  
Round and Saturate



9 bit integer

FIG. 139

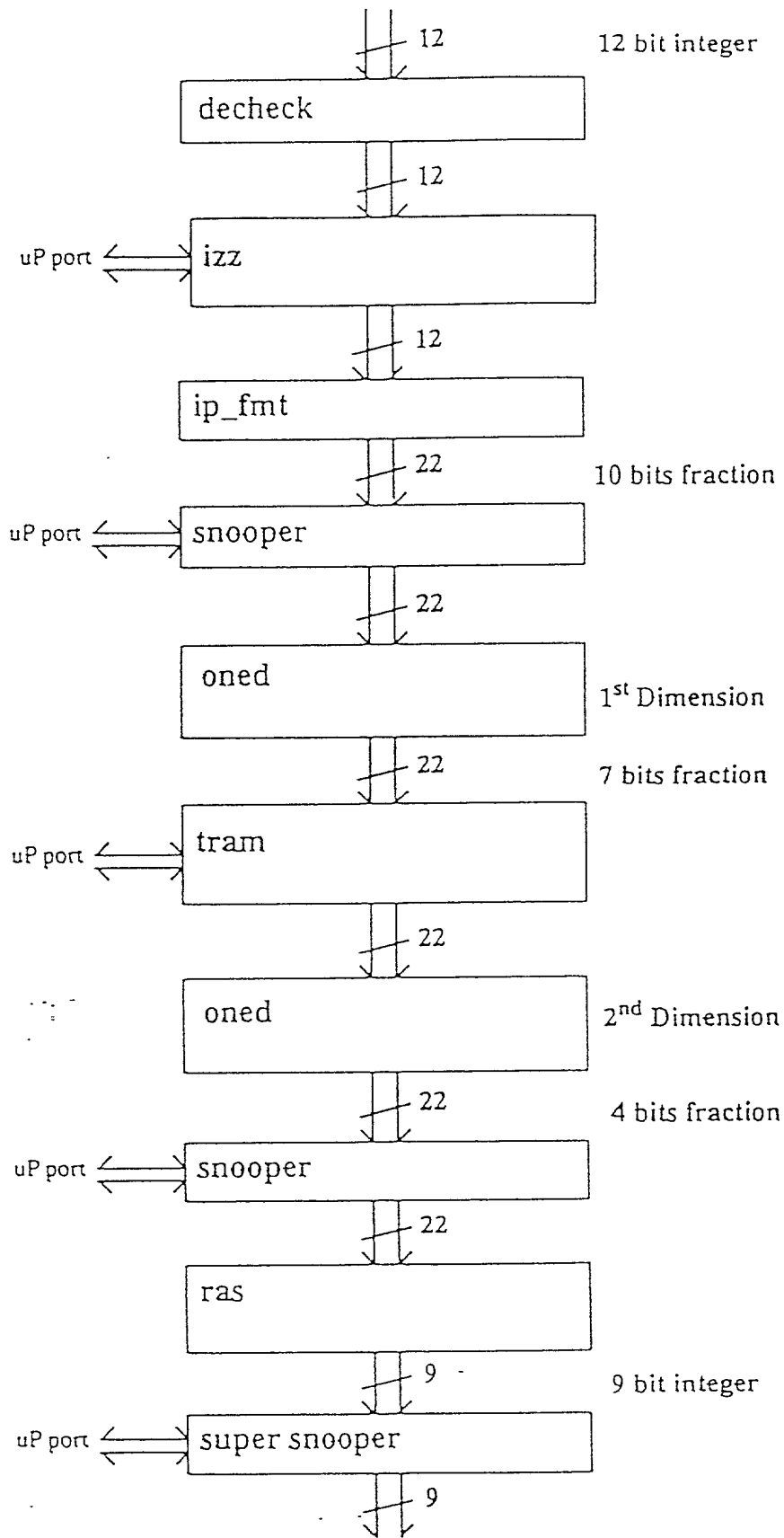
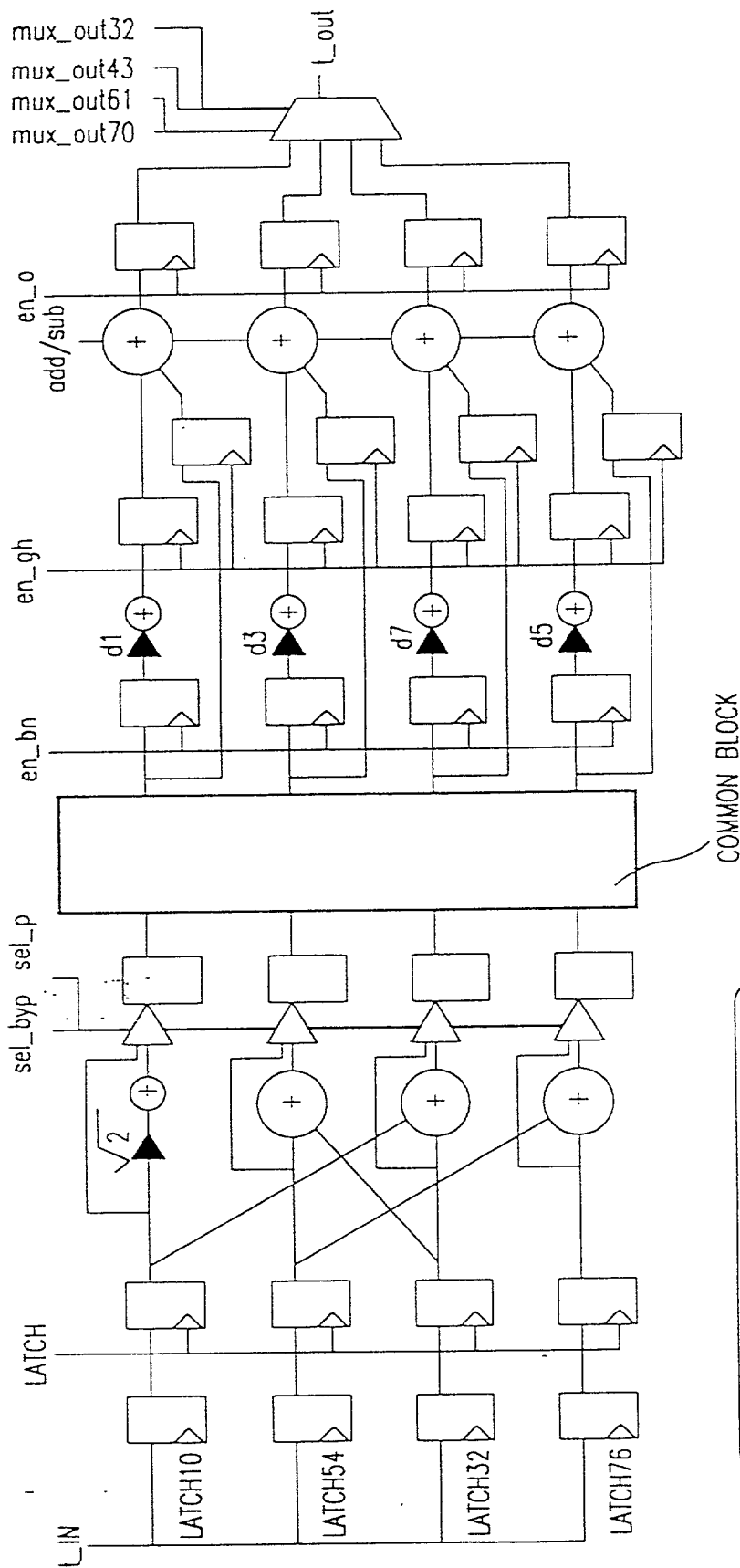


FIG. 140





NOTE: "COMMON BLOCK" IS ENTIRELY COMBINATIONAL (NO LATCHING)

FIG. 141

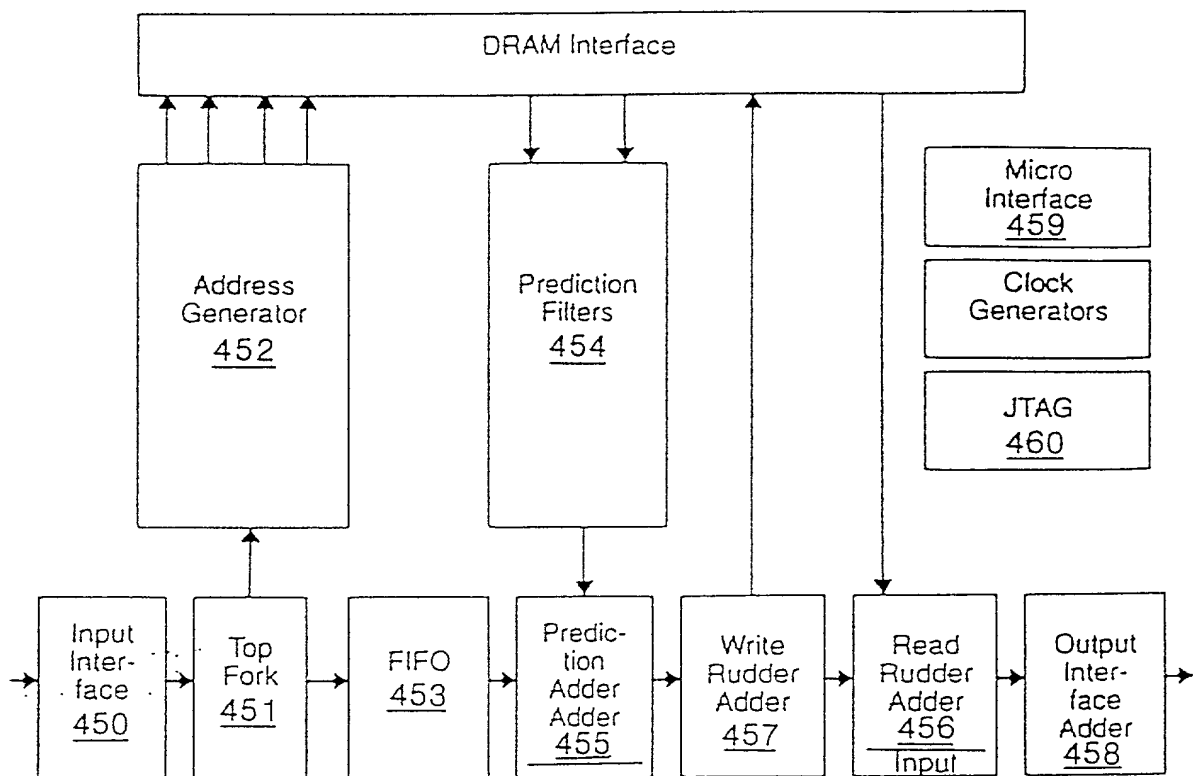


FIG. 142

0000010215960

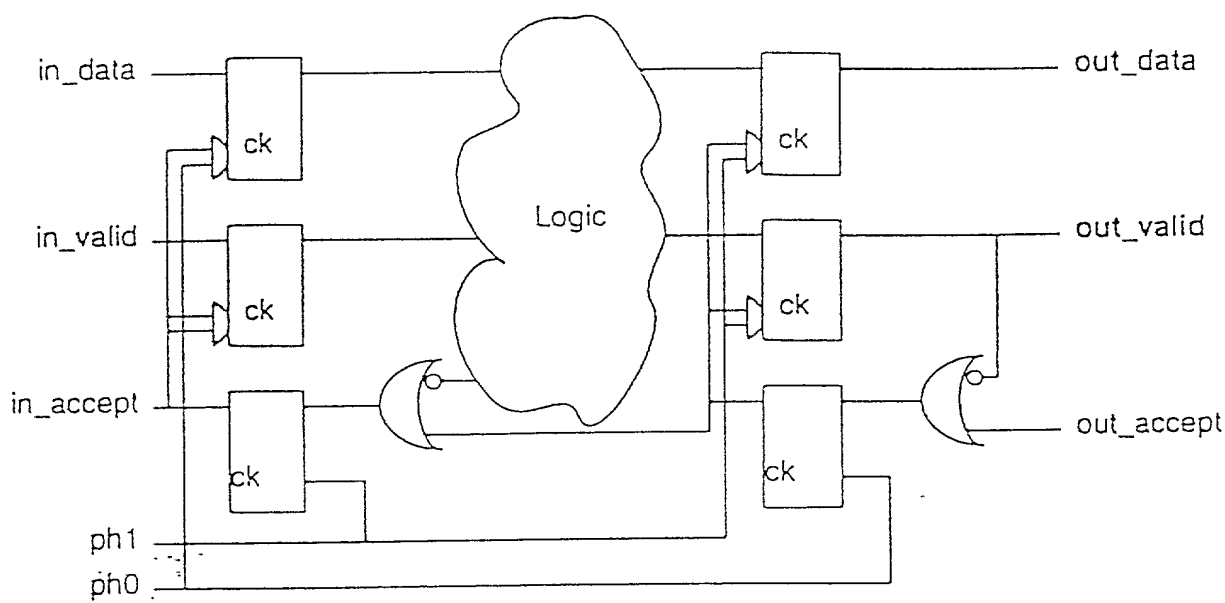


FIG. 143

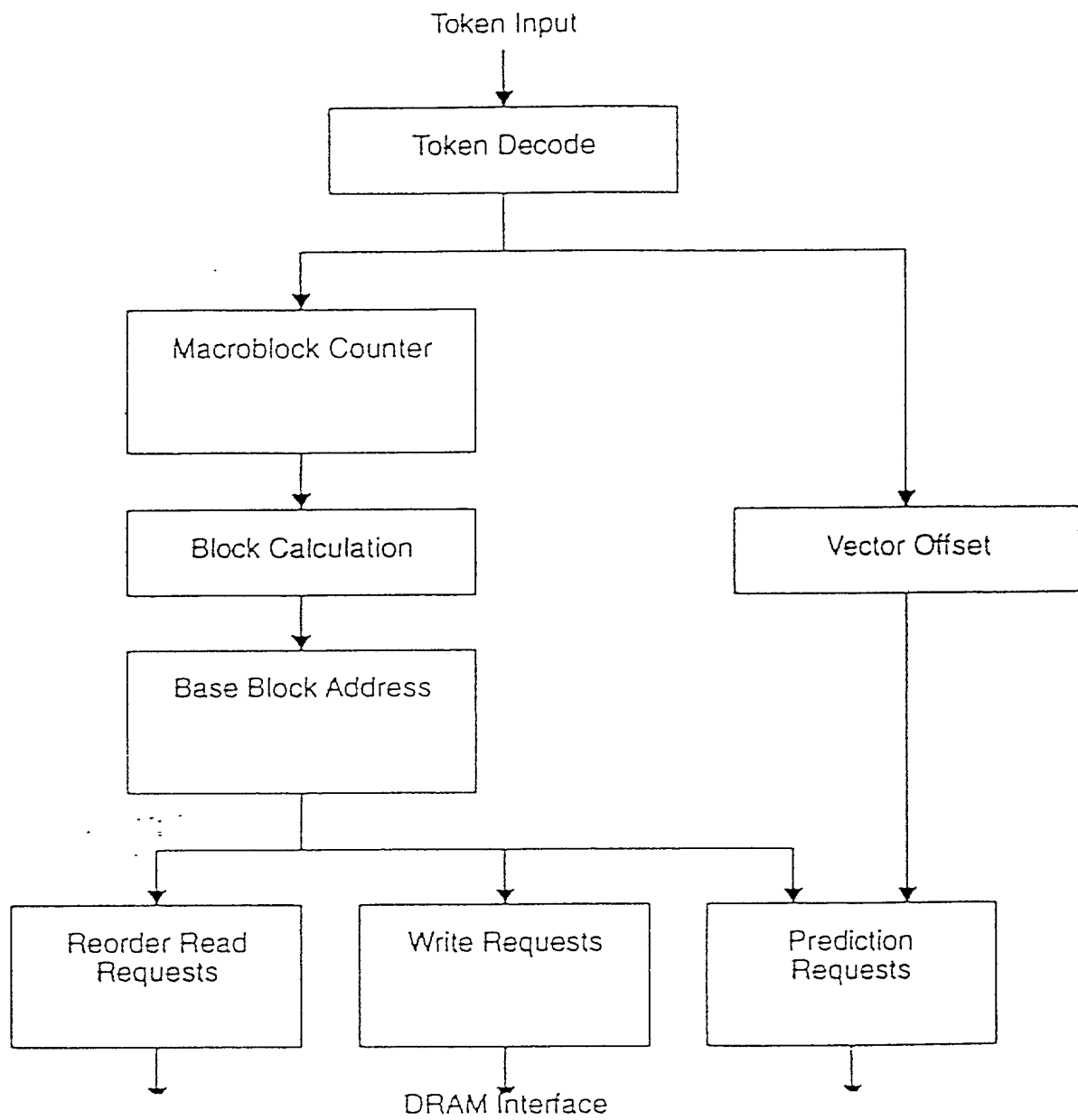


FIG. 144

The diagram illustrates the architecture of the Prediction Filter Adder (PFA). It consists of three main components: a Forward Prediction Filter, a Backward Prediction Filter, and a Prediction Filters Adder. Forward Data enters the Forward Prediction Filter, and Backward Data enters the Backward Prediction Filter. The outputs of both filters are fed into the Prediction Filters Adder. Additionally, the original Forward Data is also fed directly into the Prediction Filters Adder. The output of the Prediction Filters Adder is labeled 'To Prediction Adder'.

```
graph TD; FD[Forward Data] --> FPF[Forward Prediction Filter]; BD[Backward Data] --> BPF[Backward Prediction Filter]; FPF --> PFA[Prediction Filters Adder]; BPF --> PFA; FD --> PFA; PFA --> TPA[To Prediction Adder];
```

FIG. 146

002701 0215860

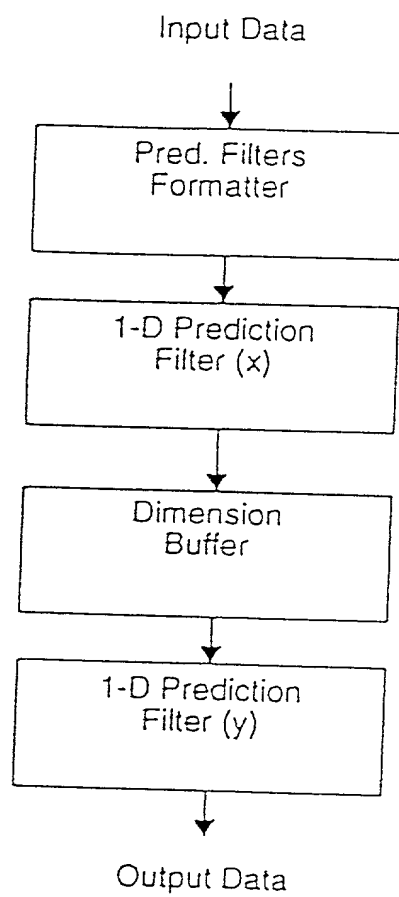


FIG. 1 47

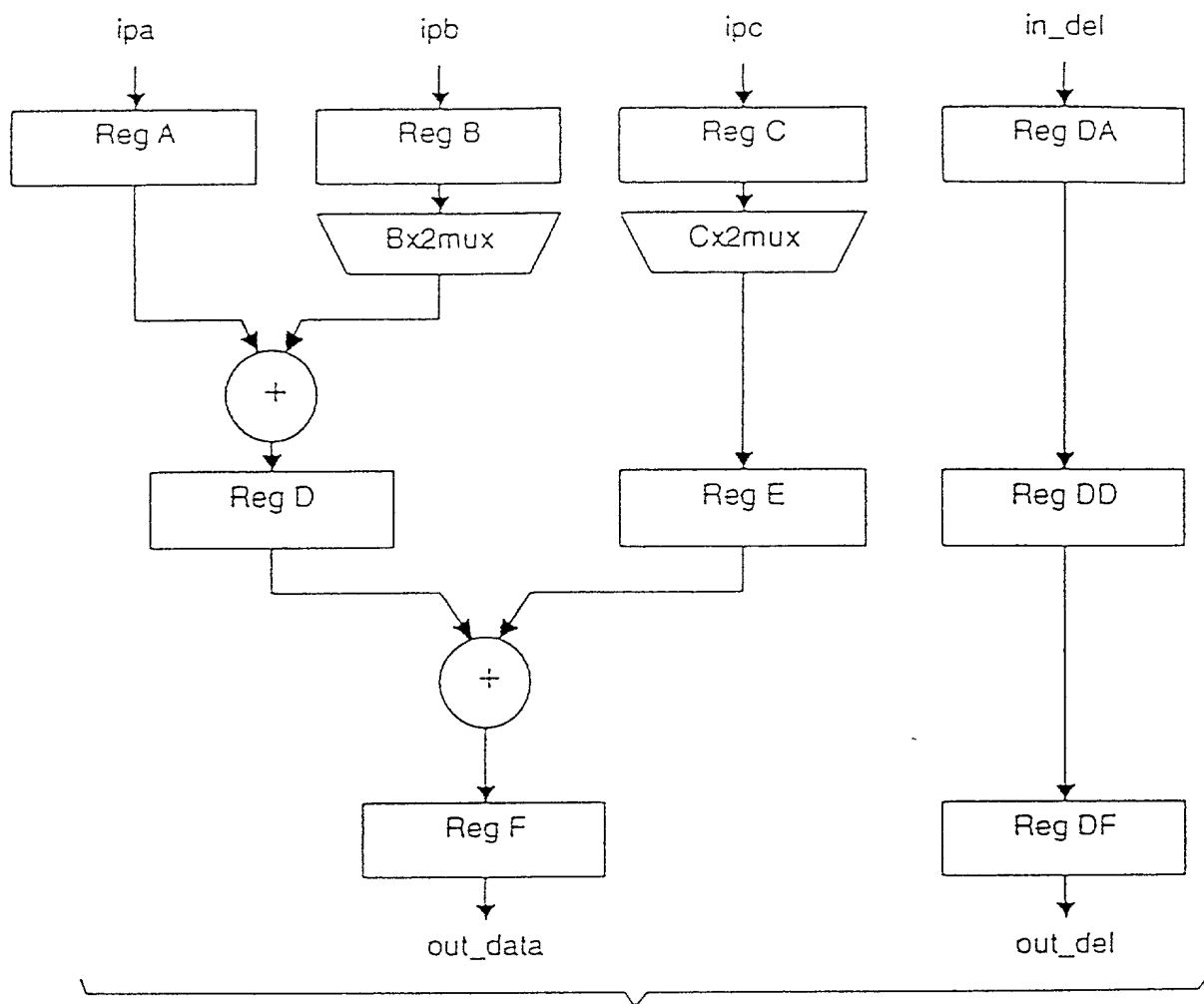


FIG. 148

|    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|
| 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
| 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
| 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 |
| 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 |

FIG. 149

FIG. 150



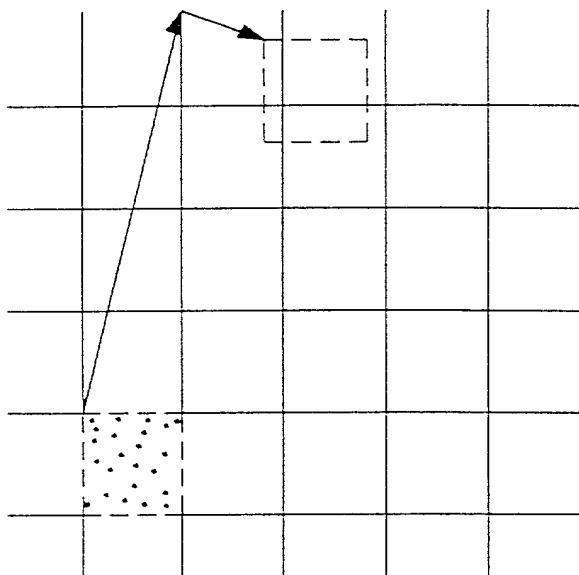


FIG. 151

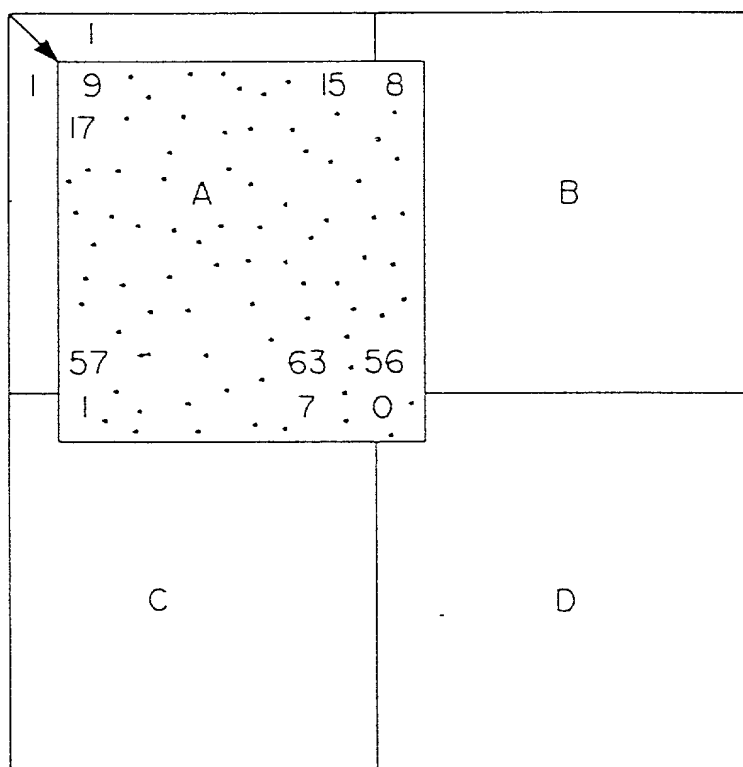


FIG. 152

## Read Cycle

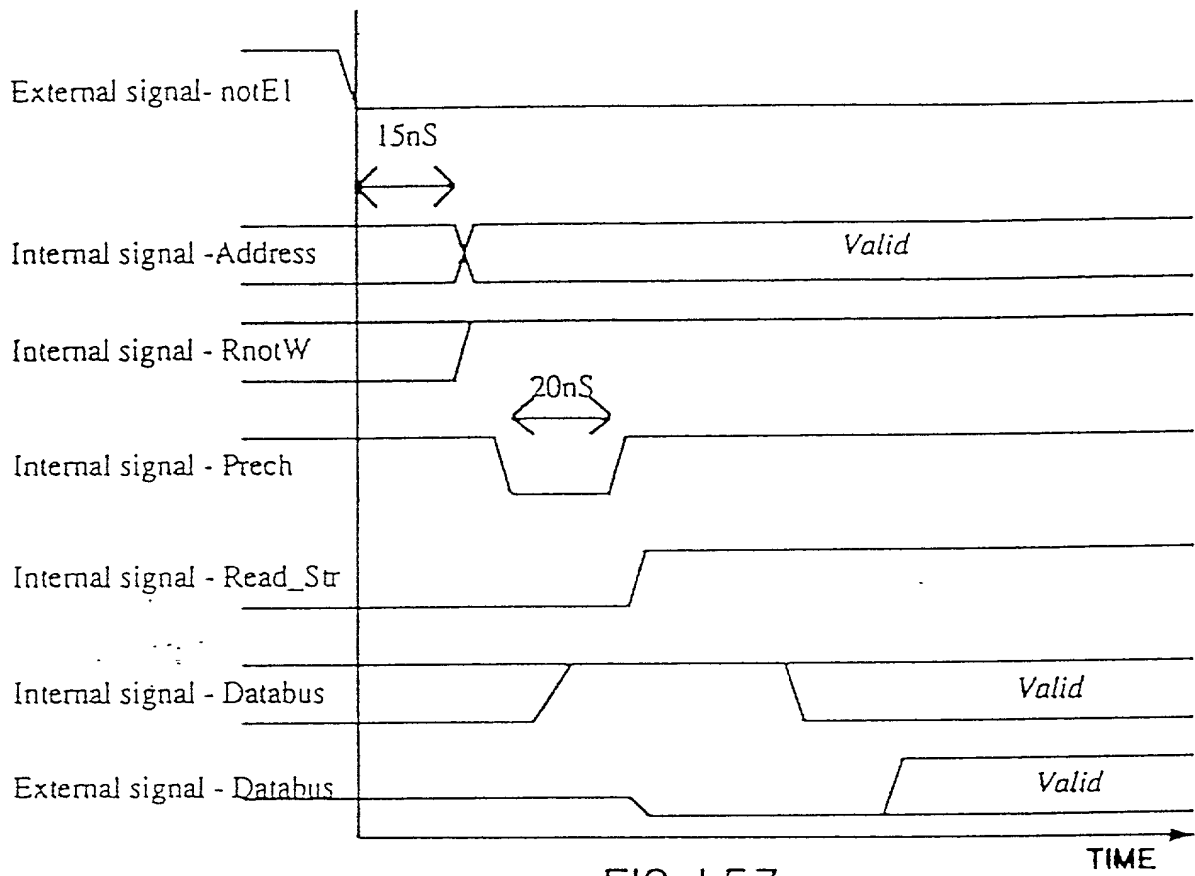


FIG. 153

## Write Cycle

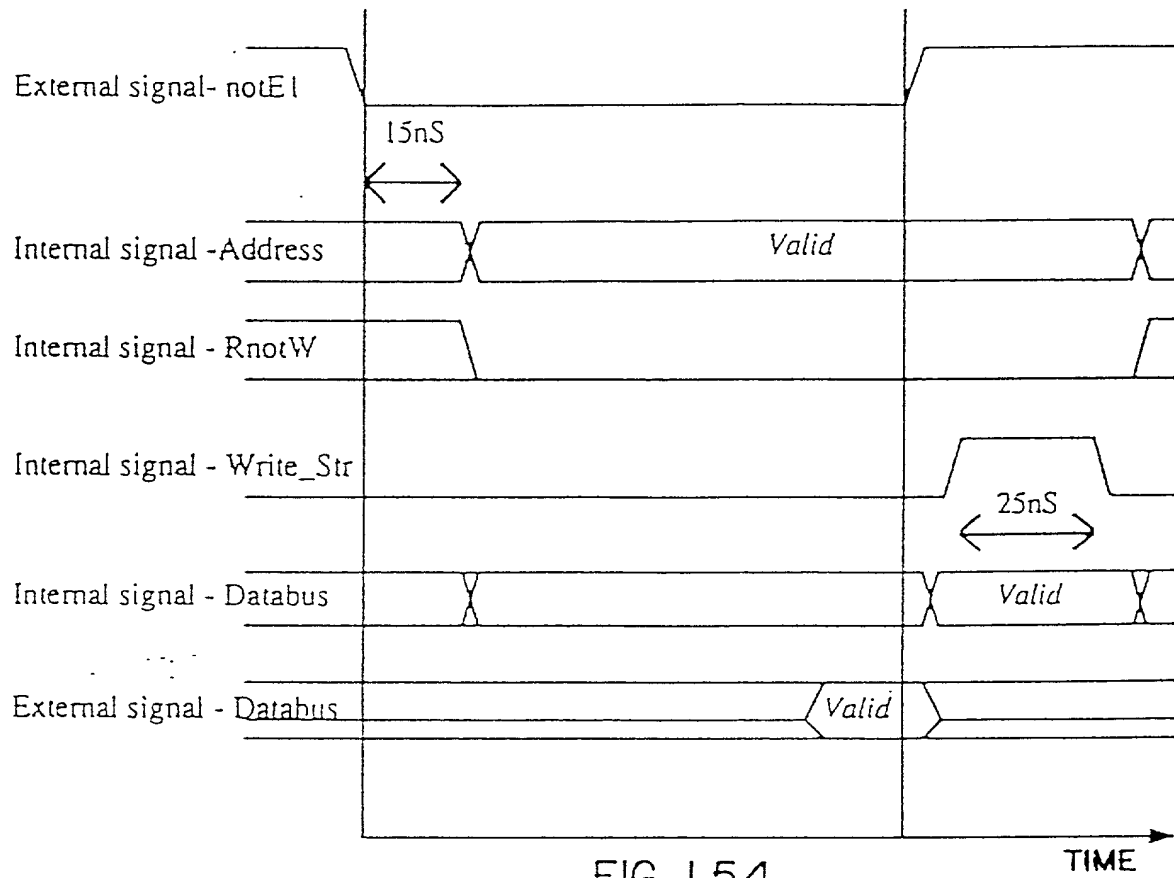


FIG. 154

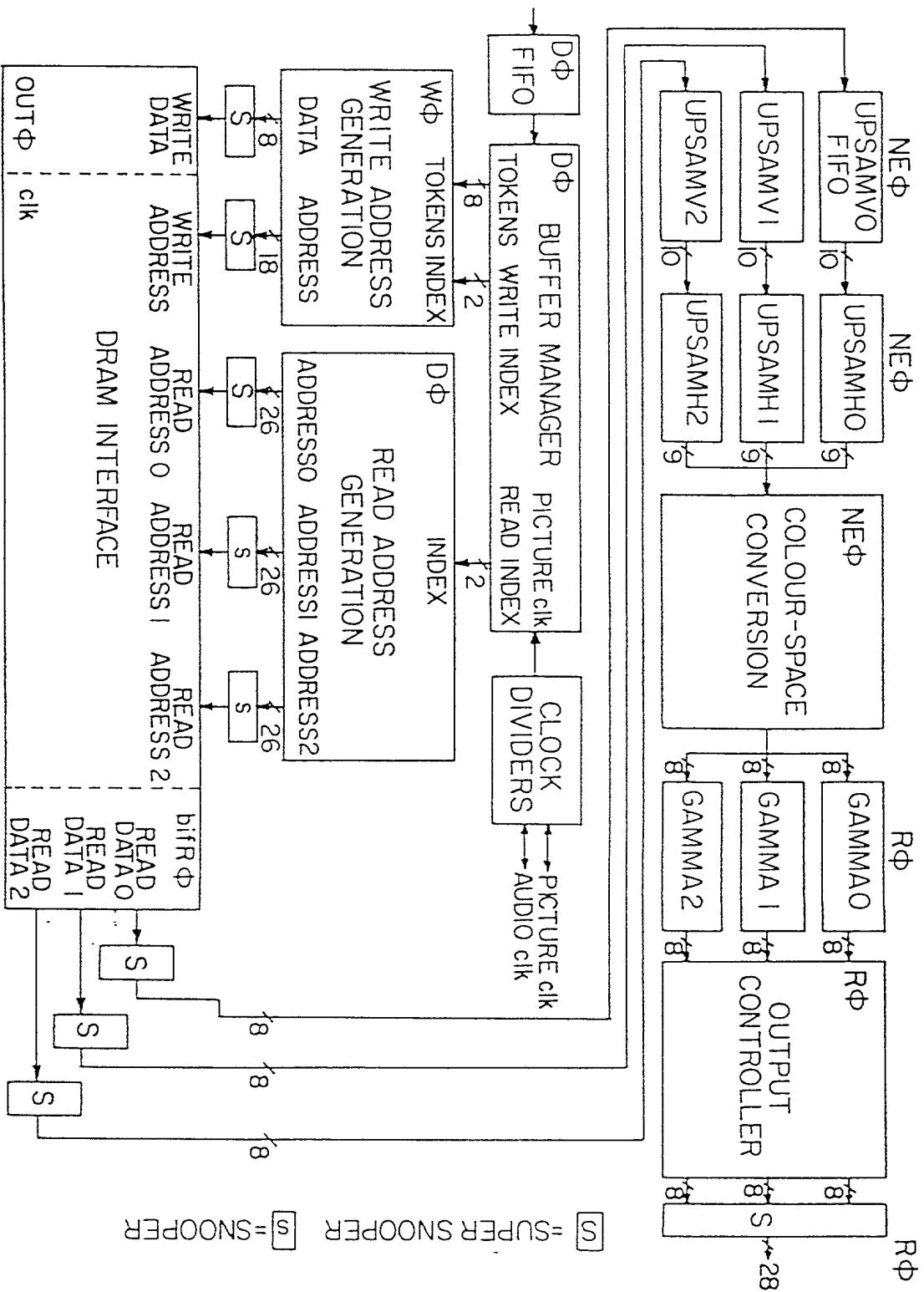


FIG. 155

002701 0215960

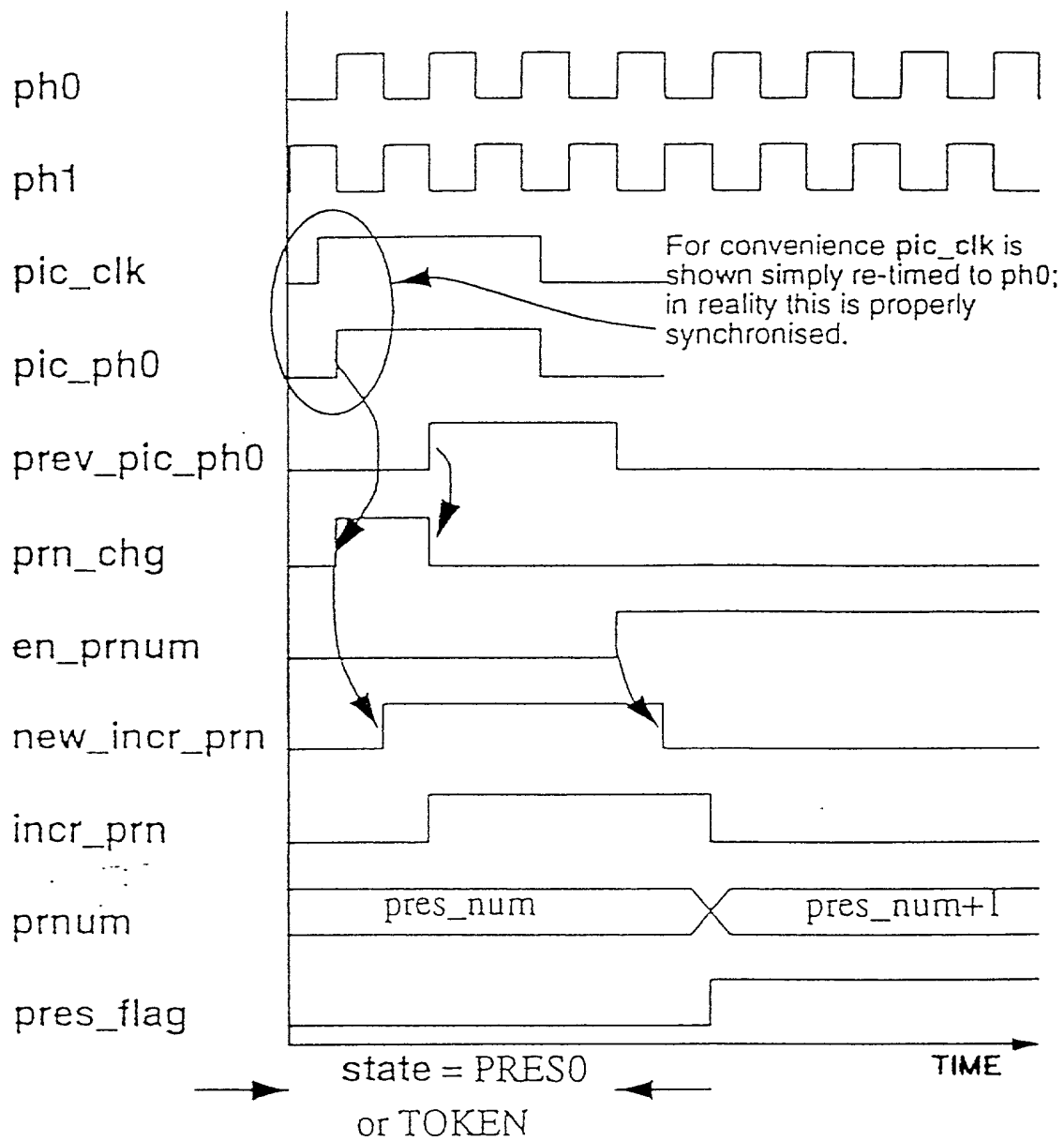


FIG. 156

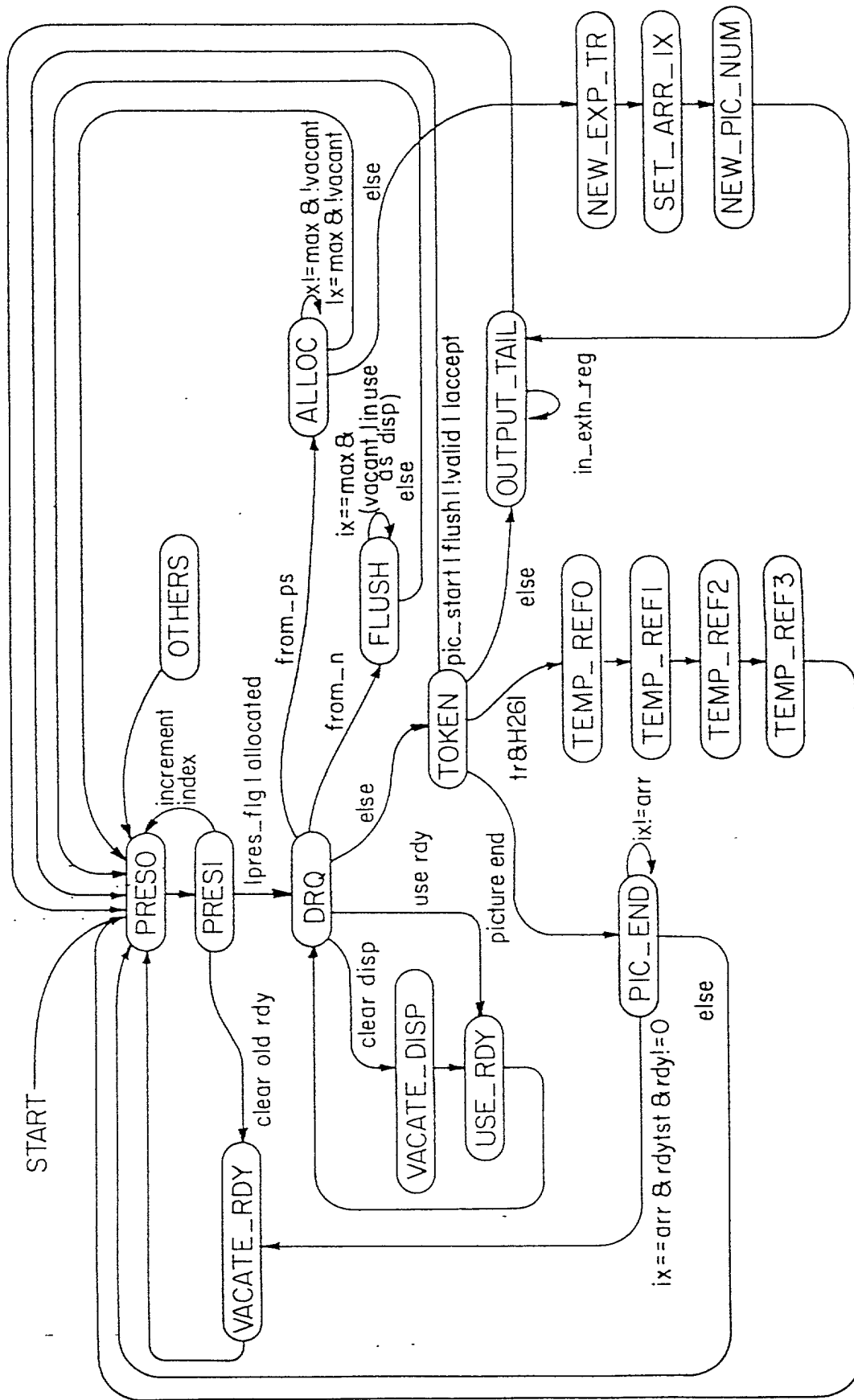


FIG. 157

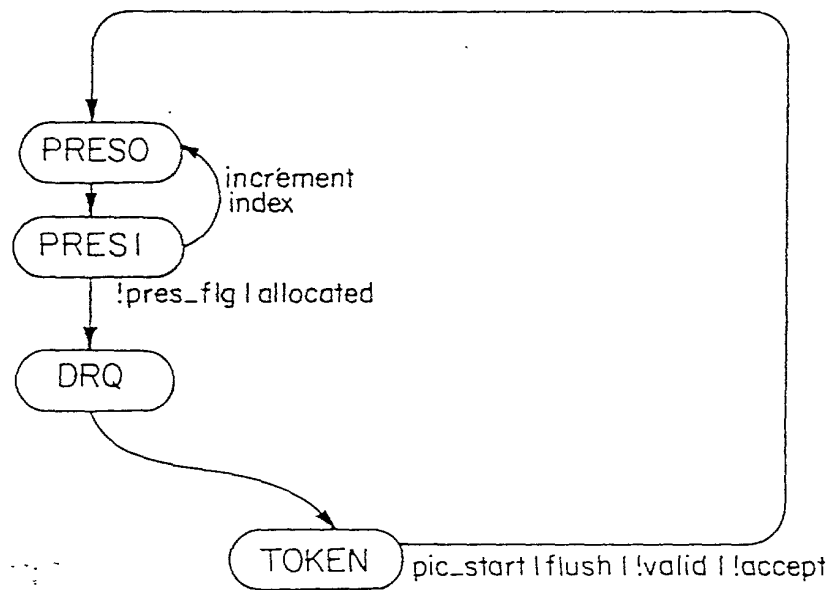
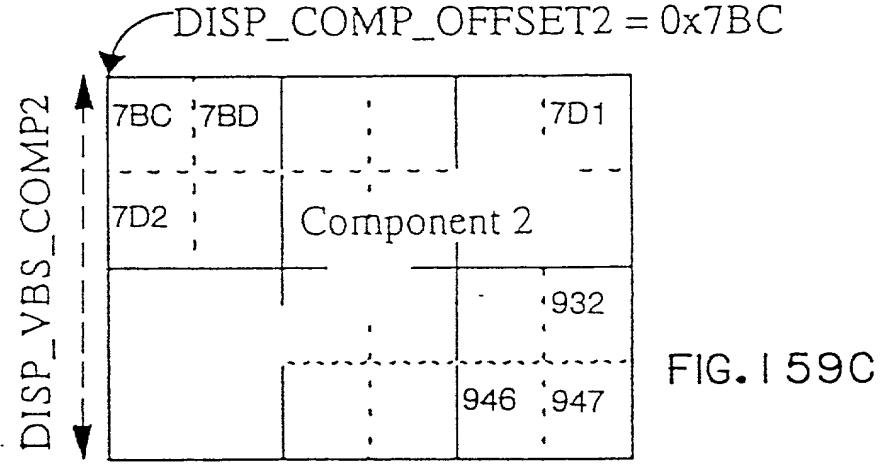
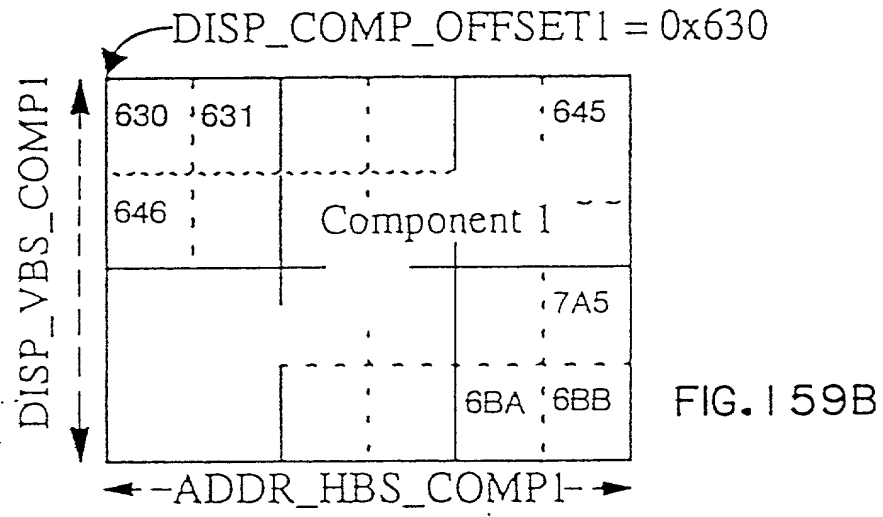
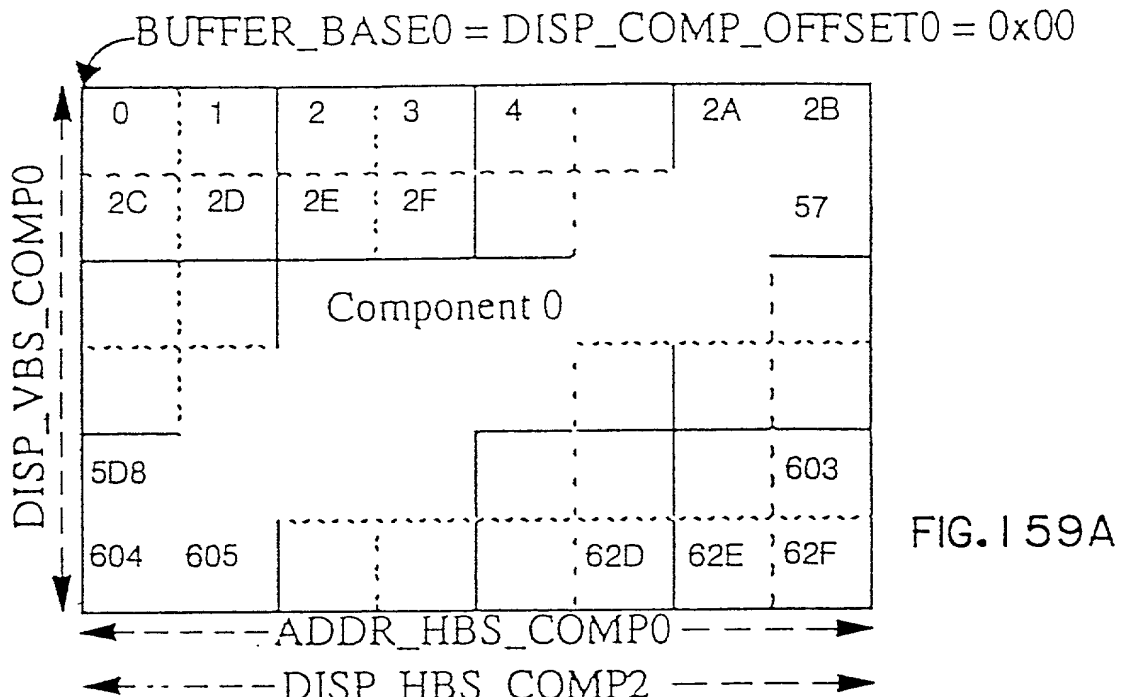
[illegible]

FIG. 158





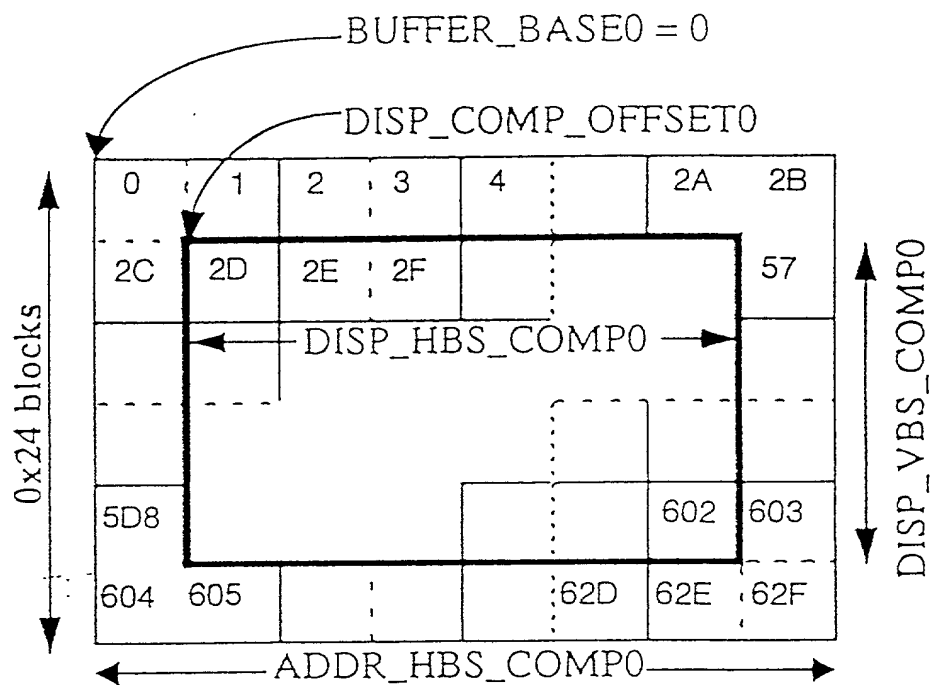


FIG. 160

BUFFER OFFSET 0x00

COMPONENT OFFSET 0x000 + .....

|    |    |    |    |    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|----|----|----|----|
| 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 0A | 0B |
| 0C | 0D | 0E | 0F | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 1A | 1B | 1C | 1D | 1E | 1F | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 2A | 2B | 2C | 2D | 2E | 2F |
| 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 3A | 3B |
| 3C | 3D | 3E | 3F | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
| 48 | 49 | 4A | 4B | 4C | 4D | 4E | 4F | 50 | 51 | 52 | 53 |
| 54 | 55 | 56 | 57 | 58 | 59 | 5A | 5B | 5C | 5D | 5E | 5F |
| 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 6A | 6B |
| 6C | 6D | 6E | 6F | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 |
| 78 | 79 | 7A | 7B | 7C | 7D | 7E | 7F | 80 | 81 | 82 | 83 |
| 84 | 85 | 86 | 87 | 88 | 89 | 8A | 8B | 8C | 8D | 8E | 8F |

FIG. 161A

COMPONENT1 OFFSET 0x100 + .....

|    |    |    |    |    |    |
|----|----|----|----|----|----|
| 00 | 01 | 02 | 03 | 04 | 05 |
| 06 | 07 | 08 | 09 | 0A | 0B |
| 0C | 0D | 0E | 0F | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 1A | 1B | 1C | 1D |
| 1E | 1F | 20 | 21 | 22 | 23 |

FIG. 161B

COMPONENT1 OFFSET 0x200 + .....

|    |    |    |    |    |    |
|----|----|----|----|----|----|
| 00 | 01 | 02 | 03 | 04 | 05 |
| 06 | 07 | 08 | 09 | 0A | 0B |
| 0C | 0D | 0E | 0F | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 1A | 1B | 1C | 1D |
| 1E | 1F | 20 | 21 | 22 | 23 |

FIG. 161C

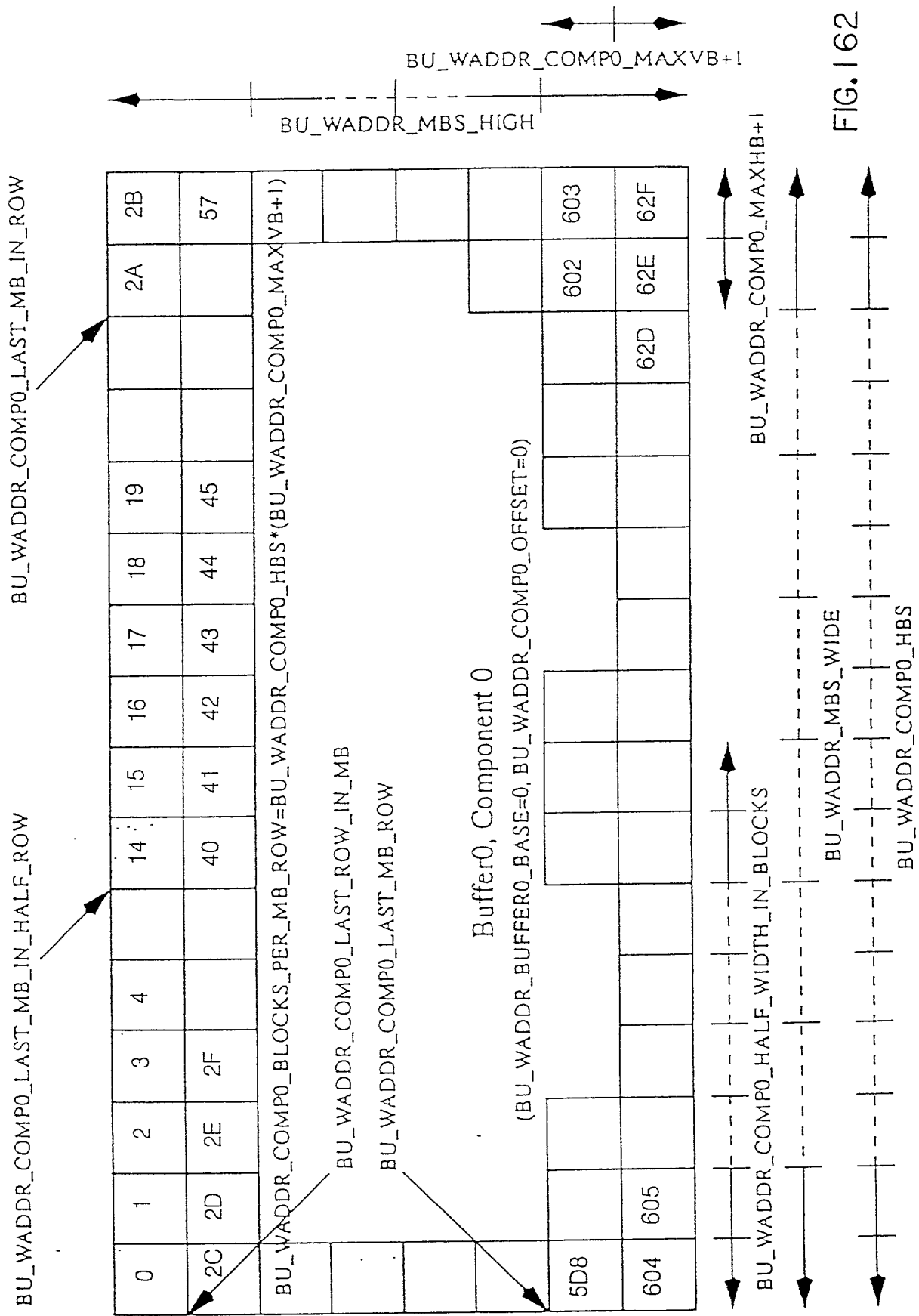
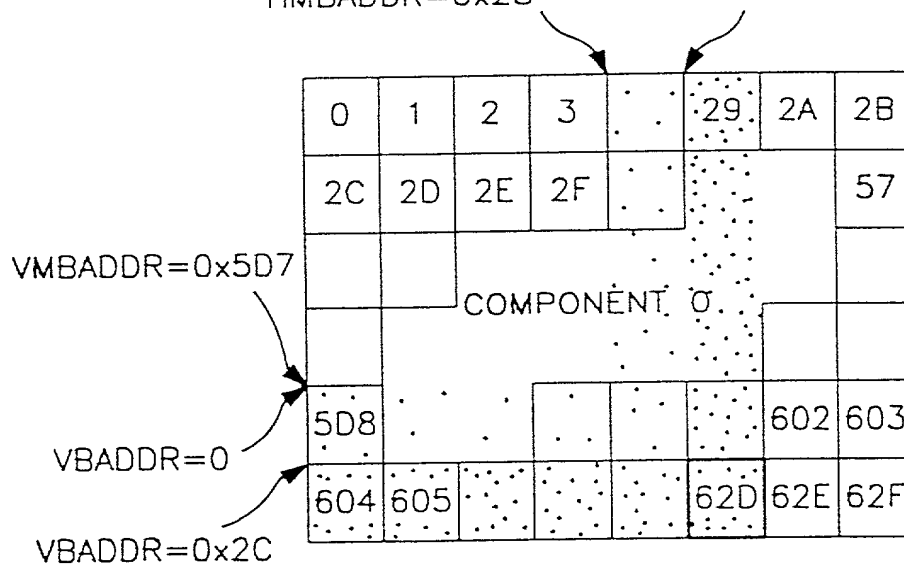
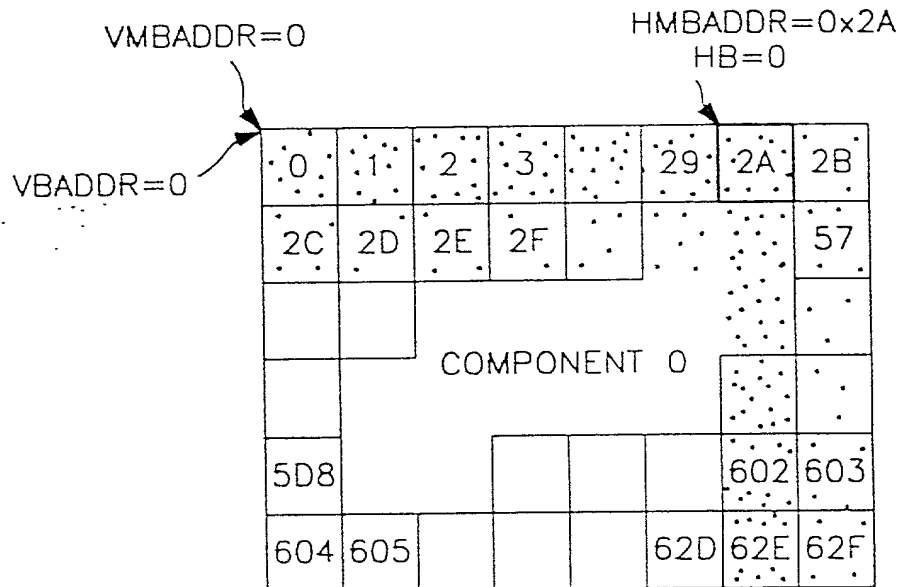


FIG. 162

$$HB=1$$


BLOCK ADDRESS =  $0 + 0 + 0 \times 5D8 + 0 \times 28 + 0 \times 2C + 1 = 0 \times 62D$

FIG. 163A



BLOCK ADDRESS =  $0 + 0 + 0 + 0 \times 2A + 0 + 0 = 0 \times 2A$

FIG. 1 63B

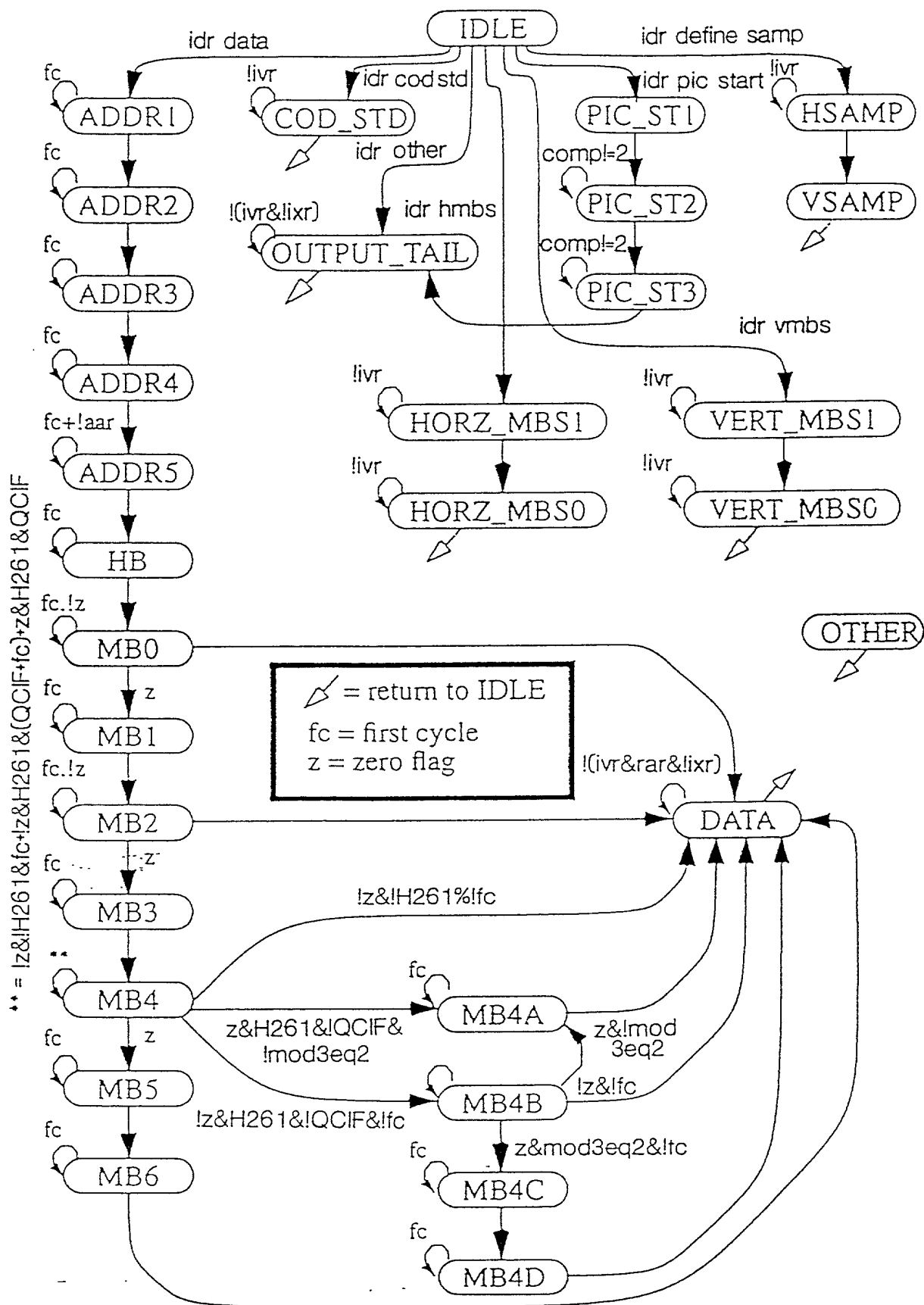


FIG. 164

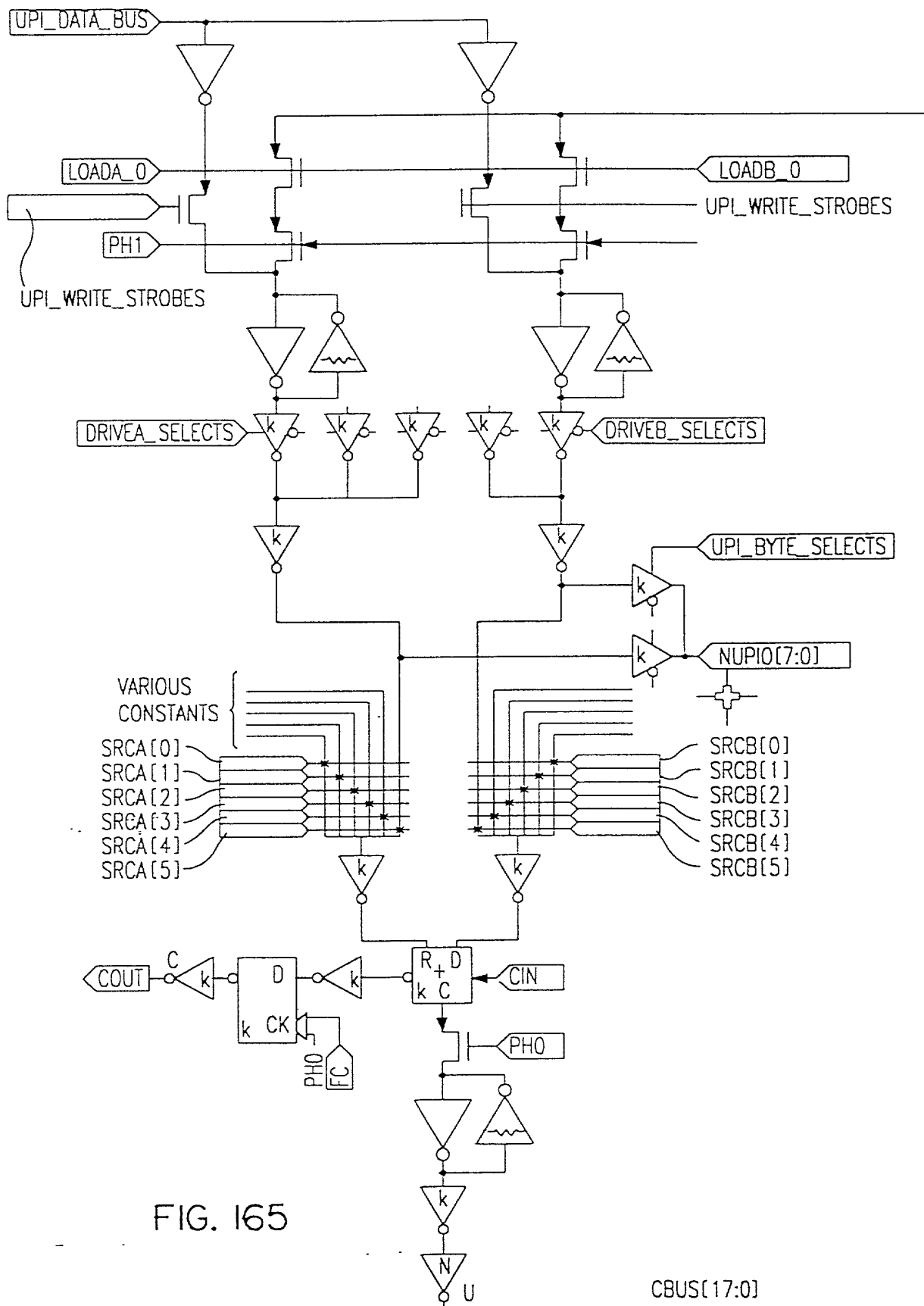


FIG. 165

Timing diagram for FIG. 166. The diagram shows the relationship between several signals over time. The signals are:

- ph1**: A periodic signal with a high period followed by a low period.
- ph0**: A periodic signal with a low period followed by a high period.
- drivea/b**: A signal that transitions from low to high and remains high for a duration.
- A/B bus**: A signal that transitions from high to low and remains low for a duration.
- Cbus**: A signal that transitions from low to high and remains high for a duration.
- LoadA\_0**: A signal that transitions from low to high and remains high for a duration.

A shaded region indicates the period when the "a" register is loaded. This region is bounded by a dashed line and occurs during the high period of the **drivea/b** signal and the low period of the **A/B bus** signal.

FIG. 166

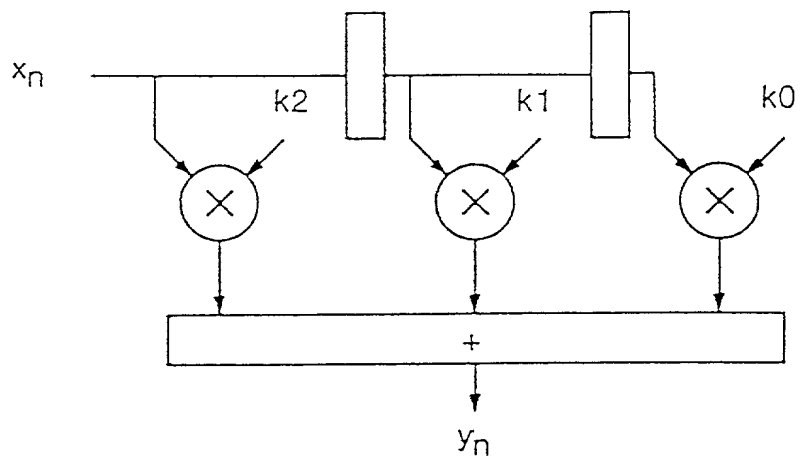


FIG. 167

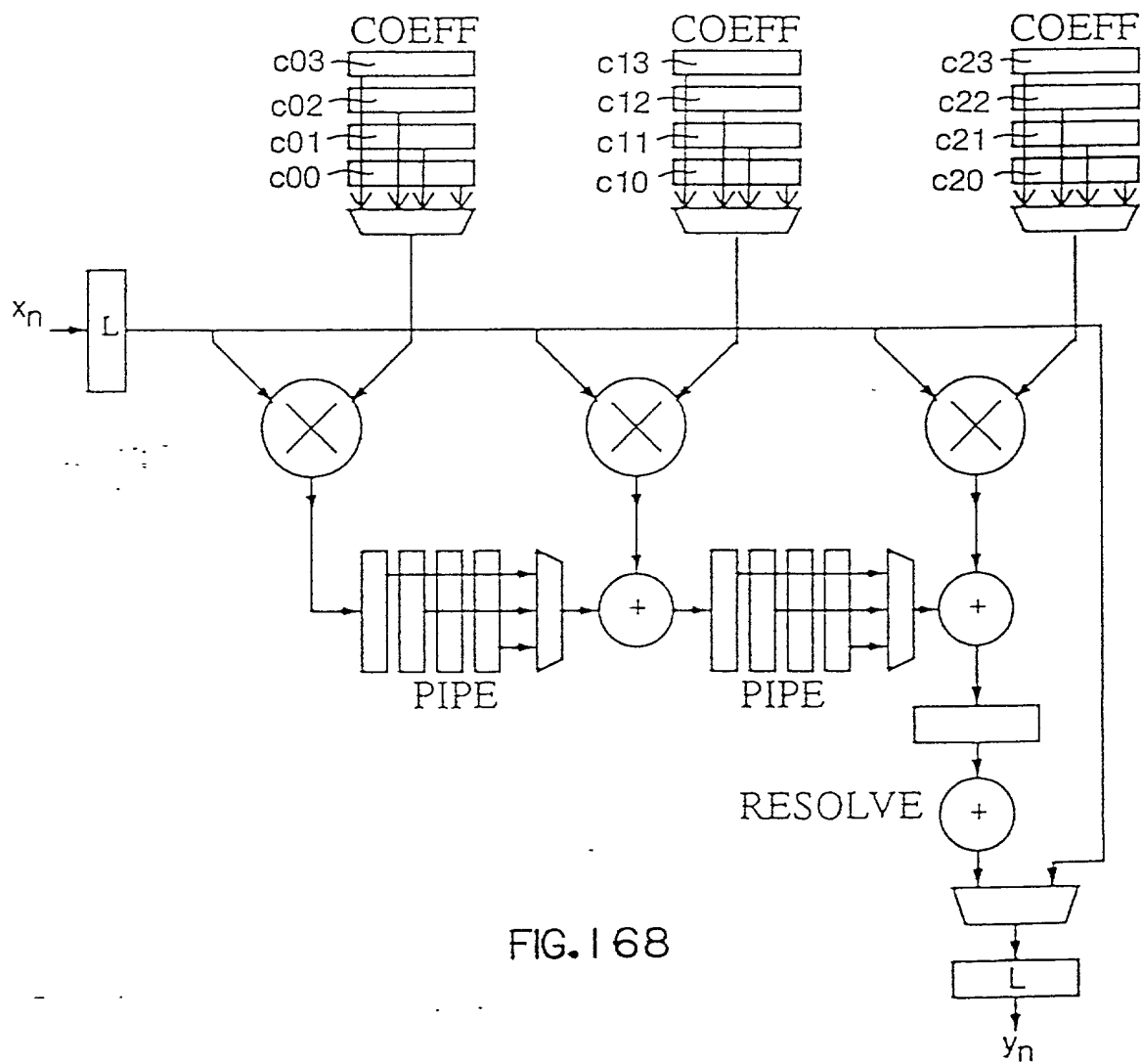


FIG. 168



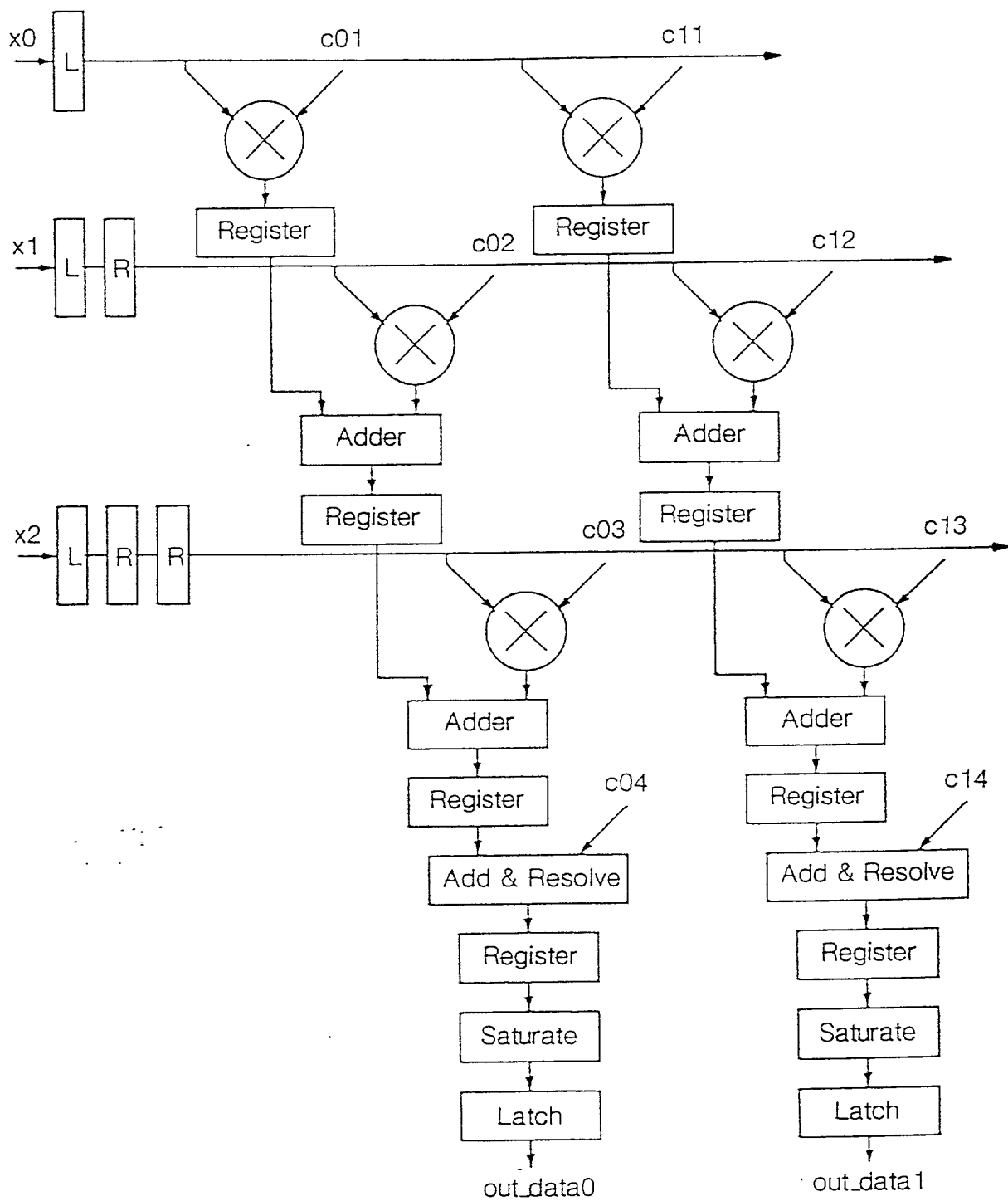


FIG. 169

# SUPPLEMENTAL DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION

|                      |                   |
|----------------------|-------------------|
| Attorney Docket Numt | 004(EP)USC1X PDDD |
| First Named Inventor | ADRIAN P. WISE    |
| COMPLETE IF KNOWN    |                   |
| Application Number   | 08/400,397        |
| Filing Date          | MARCH 7, 1995     |
| Group Art Unit       | 2302              |
| Examiner Name        | J. HARRITY        |

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

DATA PIPELINE SYSTEM AND DATA ENCODING METHOD WITH START CODE  
DETECTOR

the specification of which

(Title of the Invention)

☐ is attached hereto  
OR

☒ was filed on (MM/DD/YYYY)

03/07/1995

as United States Application Number or PCT International

11/18/1996; 02/24/1997;

Application Number

08/400,397

and was amended on (MM/DD/YYYY)

06/11/1997

(if applicable).

I hereby declare that the subject matter of the ☐ attached amendment ☐ amendment filed on was part of my or our invention and was invented before the filing date of the original application, above identified for such invention.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations, § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code § 119 (a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365 (a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

| Prior Foreign Application Number(s) | Country       | Foreign Filing Date (MM/DD/YYYY) | Priority Not Claimed     | Certified Copy Attached? |                                     |
|-------------------------------------|---------------|----------------------------------|--------------------------|--------------------------|-------------------------------------|
|                                     |               |                                  |                          | YES                      | NO                                  |
| 92306038.8                          | EPO           | 06/30/1992                       | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 9405914.4                           | GREAT BRITAIN | 03/24/1994                       | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 9504019.2                           | GREAT BRITAIN | 02/28/1995                       | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
|                                     |               |                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            |
|                                     |               |                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            |
|                                     |               |                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            |

☐ Additional foreign application numbers are listed on a supplemental priority sheet attached hereto:

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below.

| Application Number(s) | Filing Date (MM/DD/YYYY) | <input type="checkbox"/> Additional provisional application numbers are listed on a supplemental priority sheet attached hereto |
|-----------------------|--------------------------|---------------------------------------------------------------------------------------------------------------------------------|
|                       |                          |                                                                                                                                 |

[Page 1 of 5]

Burden Hour Statement: This form is estimated to take 0.4 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner of Patents and Trademarks, Washington, DC 20231.

Type a plus sign (+) in this box → ☐PTO/SB/04 (8-96)  
Approved for use through 9/30/98. OMB 0651-0032  
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

## DECLARATION

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s), or §365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application

| U.S. Parent Application Number | PCT Parent Number | Parent Filing Date (MM/DD/YYYY) | Parent Patent Number (if applicable) |
|--------------------------------|-------------------|---------------------------------|--------------------------------------|
| 08/082,291<br>08/382,952       |                   | 06/24/1993<br>02/01/1995        | 5,519,339                            |

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority sheet attached hereto.

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

| Name             | Registration Number | Name | Registration Number |
|------------------|---------------------|------|---------------------|
| Ronald J. Clark  | 21,058              |      |                     |
| Robert T. Braun  | 36,758              |      |                     |
| Arthur S. Bickel | 34,123              |      |                     |

☐ Additional registered practitioner(s) named on a supplemental sheet attached hereto.

Direct all correspondence to:


|         |                             |           |                |
|---------|-----------------------------|-----------|----------------|
| Name    | Robert T. Braun             |           |                |
| Address | 2355 Main Street, Suite 200 |           |                |
| Address |                             |           |                |
| City    | Irvine                      | State     | CA             |
|         |                             | ZIP       | 92614          |
| Country | USA                         | Telephone | (714) 660-5000 |
|         |                             | Fax       | (714) 660-1801 |

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor:

☐ A petition has been filed for this unsigned inventor

|            |        |                |   |             |      |                 |  |
|------------|--------|----------------|---|-------------|------|-----------------|--|
| Given Name | ADRIAN | Middle Initial | P | Family Name | WISE | Suffix e.g. Jr. |  |
|------------|--------|----------------|---|-------------|------|-----------------|--|

|                      |                                                                                     |      |            |
|----------------------|-------------------------------------------------------------------------------------|------|------------|
| Inventor's Signature |  | Date | 17 July 97 |
|----------------------|-------------------------------------------------------------------------------------|------|------------|

|                 |                  |       |  |         |                |             |    |
|-----------------|------------------|-------|--|---------|----------------|-------------|----|
| Residence: City | BRACKNELL, BERKS | State |  | Country | UNITED KINGDOM | Citizenship | UK |
|-----------------|------------------|-------|--|---------|----------------|-------------|----|

|                     |               |
|---------------------|---------------|
| Post Office Address | 17 ALBEN ROAD |
|---------------------|---------------|

|                     |          |
|---------------------|----------|
| Post Office Address | BINFIELD |
|---------------------|----------|

|      |           |       |  |     |          |         |                |
|------|-----------|-------|--|-----|----------|---------|----------------|
| City | BRACKNELL | State |  | Zip | RG42 4HU | Country | UNITED KINGDOM |
|------|-----------|-------|--|-----|----------|---------|----------------|

☒ Additional inventors are being named on supplemental sheet(s) attached hereto

Type a plus sign (+) in this box → ☐

|                    |                                                      |
|--------------------|------------------------------------------------------|
| <b>DECLARATION</b> | <b>ADDITIONAL INVENTOR(S)<br/>Supplemental Sheet</b> |
|--------------------|------------------------------------------------------|


|                                                                                                                   |                              |                |   |             |                                                                               |                    |                           |  |  |
|-------------------------------------------------------------------------------------------------------------------|------------------------------|----------------|---|-------------|-------------------------------------------------------------------------------|--------------------|---------------------------|--|--|
| Name of Additional Joint Inventor, if any:                                                                        |                              |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |                    |                           |  |  |
| Given Name                                                                                                        | MARTIN                       | Middle Initial | W | Family Name | SOTHERAN                                                                      | Suffix<br>e.g. Jr. |                           |  |  |
| Inventor's Signature                                                                                              |                              |                |   |             |                                                                               | Date               | 7 <sup>th</sup> July '97. |  |  |
| Residence: City                                                                                                   | BRISTOL                      | State          |   | Country     | UNITED KINGDOM                                                                | Citizenship        | UK                        |  |  |
| Post Office Address                                                                                               | 24 HOME FARM WAY             |                |   |             |                                                                               |                    |                           |  |  |
| Post Office Address                                                                                               | EASTER COMPTON               |                |   |             |                                                                               |                    |                           |  |  |
| City                                                                                                              | BRISTOL                      | State          |   | Zip         | BS12 3SE                                                                      | Country            | UNITED KINGDOM            |  |  |
| Name of Additional Joint Inventor, if any:                                                                        |                              |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |                    |                           |  |  |
| Given Name                                                                                                        | WILLIAM                      | Middle Initial | P | Family Name | ROBBINS                                                                       | Suffix<br>e.g. Jr. |                           |  |  |
| Inventor's Signature                                                                                              |                              |                |   |             |                                                                               | Date               |                           |  |  |
| Residence: City                                                                                                   | BRISTOL                      | State          |   | Country     | UNITED KINGDOM                                                                | Citizenship        | UK                        |  |  |
| Post Office Address                                                                                               | 2 WINDSOR TERRACE            |                |   |             |                                                                               |                    |                           |  |  |
| Post Office Address                                                                                               | CLIFTON                      |                |   |             |                                                                               |                    |                           |  |  |
| City                                                                                                              | BRISTOL                      | State          |   | Zip         | BS8 4LW                                                                       | Country            | UNITED KINGDOM            |  |  |
| Name of Additional Joint Inventor, if any:                                                                        |                              |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |                    |                           |  |  |
| Given Name                                                                                                        | ANTHONY                      | Middle Initial | M | Family Name | JONES                                                                         | Suffix<br>e.g. Jr. |                           |  |  |
| Inventor's Signature                                                                                              |                              |                |   |             |                                                                               | Date               |                           |  |  |
| Residence: City                                                                                                   | NIJMEGEN                     | State          |   | Country     | NETHERLANDS                                                                   | Citizenship        | UK                        |  |  |
| Post Office Address                                                                                               | NIJMEEGSEBAAN 45 CB NIJMEGEN |                |   |             |                                                                               |                    |                           |  |  |
| Post Office Address                                                                                               | HEILIG LAND STICHTING        |                |   |             |                                                                               |                    |                           |  |  |
| City                                                                                                              | NIJMEGEN                     | State          |   | Zip         | 6564                                                                          | Country            | UNITED KINGDOM            |  |  |
| Name of Additional Joint Inventor, if any:                                                                        |                              |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |                    |                           |  |  |
| Given Name                                                                                                        | HELEN                        | Middle Initial | R | Family Name | FINCH                                                                         | Suffix<br>e.g. Jr. |                           |  |  |
| Inventor's Signature                                                                                              |                              |                |   |             |                                                                               | Date               |                           |  |  |
| Residence: City                                                                                                   | BRISTOL                      | State          |   | Country     | UNITED KINGDOM                                                                | Citizenship        | UK                        |  |  |
| Post Office Address                                                                                               | 41 DRUID WOODS - AVON WAY    |                |   |             |                                                                               |                    |                           |  |  |
| Post Office Address                                                                                               |                              |                |   |             |                                                                               |                    |                           |  |  |
| City                                                                                                              | BRISTOL                      | State          |   | Zip         | BS9 1SZ                                                                       | Country            | UNITED KINGDOM            |  |  |
| <input checked="" type="checkbox"/> Additional inventors are being named on supplemental sheet(s) attached hereto |                              |                |   |             |                                                                               |                    |                           |  |  |

002207 02768960

+

## DECLARATION

ADDITIONAL INVENTOR(S)  
Supplemental Sheet

|                                                                                                                   |                                                                                   |                |   |             |                                                                               |             |                |  |  |
|-------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|----------------|---|-------------|-------------------------------------------------------------------------------|-------------|----------------|--|--|
| Name of Additional Joint Inventor, if any:                                                                        |                                                                                   |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                                        | MARTIN                                                                            | Middle Initial | W | Family Name | SOTHERAN                                                                      | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                              |                                                                                   |                |   |             |                                                                               | Date        |                |  |  |
| Residence: City                                                                                                   | BRISTOL                                                                           | State          |   | Country     | UNITED KINGDOM                                                                | Citizenship | UK             |  |  |
| Post Office Address                                                                                               | 24 HOME FARM WAY                                                                  |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                               | EASTER COMPTON                                                                    |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                              | BRISTOL                                                                           | State          |   | Zip         | BS12 3SE                                                                      | Country     | UNITED KINGDOM |  |  |
| Name of Additional Joint Inventor, if any:                                                                        |                                                                                   |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                                        | WILLIAM                                                                           | Middle Initial | P | Family Name | ROBBINS                                                                       | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                              |  |                |   |             |                                                                               | Date        | 8 July 97      |  |  |
| Residence: City                                                                                                   | BRISTOL                                                                           | State          |   | Country     | UNITED KINGDOM                                                                | Citizenship | UK             |  |  |
| Post Office Address                                                                                               | 2 WINDSOR TERRACE                                                                 |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                               | CLIFTON                                                                           |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                              | BRISTOL                                                                           | State          |   | Zip         | BS8 4LW                                                                       | Country     | UNITED KINGDOM |  |  |
| Name of Additional Joint Inventor, if any:                                                                        |                                                                                   |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                                        | ANTHONY                                                                           | Middle Initial | M | Family Name | JONES                                                                         | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                              |                                                                                   |                |   |             |                                                                               | Date        |                |  |  |
| Residence: City                                                                                                   | NIJMEGEN                                                                          | State          |   | Country     | NETHERLANDS                                                                   | Citizenship | UK             |  |  |
| Post Office Address                                                                                               | NIJMEEGSEBAAN 45 CB NIJMEGEN                                                      |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                               | HEILIG LAND STICHTING                                                             |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                              | NIJMEGEN                                                                          | State          |   | Zip         | 6564                                                                          | Country     | UNITED KINGDOM |  |  |
| Name of Additional Joint Inventor, if any:                                                                        |                                                                                   |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                                        | HELEN                                                                             | Middle Initial | R | Family Name | FINCH                                                                         | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                              |                                                                                   |                |   |             |                                                                               | Date        |                |  |  |
| Residence: City                                                                                                   | BRISTOL                                                                           | State          |   | Country     | UNITED KINGDOM                                                                | Citizenship | UK             |  |  |
| Post Office Address                                                                                               | 41 DRUID WOODS - AVON WAY                                                         |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                               |                                                                                   |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                              | BRISTOL                                                                           | State          |   | Zip         | BS9 1SZ                                                                       | Country     | UNITED KINGDOM |  |  |
| <input checked="" type="checkbox"/> Additional inventors are being named on supplemental sheet(s) attached hereto |                                                                                   |                |   |             |                                                                               |             |                |  |  |

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PTO/SB/04 (8-96)  
Approved for use through 9/30/98. OMB 0651-0032  
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

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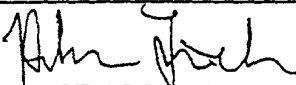
## DECLARATION

ADDITIONAL INVENTOR(S)  
Supplemental Sheet

|                                                                                                                   |                           |                |   |                                                                               |                |             |                |
|-------------------------------------------------------------------------------------------------------------------|---------------------------|----------------|---|-------------------------------------------------------------------------------|----------------|-------------|----------------|
| Name of Additional Joint Inventor, if any:                                                                        |                           |                |   | <input type="checkbox"/> A petition has been filed for this unsigned inventor |                |             |                |
| Given Name                                                                                                        | MARTIN                    | Middle Initial | W | Family Name                                                                   | SOTHERAN       | Suffix      |                |
| Inventor's Signature                                                                                              |                           |                |   |                                                                               |                | Date        |                |
| Residence: City                                                                                                   | BRISTOL                   | State          |   | Country                                                                       | UNITED KINGDOM | Citizenship | UK             |
| Post Office Address                                                                                               | 24 HOME FARM WAY          |                |   |                                                                               |                |             |                |
| Post Office Address                                                                                               | EASTER COMPTON            |                |   |                                                                               |                |             |                |
| City                                                                                                              | BRISTOL                   | State          |   | Zip                                                                           | BS12 3SE       | Country     | UNITED KINGDOM |
| Name of Additional Joint Inventor, if any:                                                                        |                           |                |   | <input type="checkbox"/> A petition has been filed for this unsigned inventor |                |             |                |
| Given Name                                                                                                        | WILLIAM                   | Middle Initial | P | Family Name                                                                   | ROBBINS        | Suffix      |                |
| Inventor's Signature                                                                                              |                           |                |   |                                                                               |                | Date        |                |
| Residence: City                                                                                                   | BRISTOL                   | State          |   | Country                                                                       | UNITED KINGDOM | Citizenship | UK             |
| Post Office Address                                                                                               | 2 WINDSOR TERRACE         |                |   |                                                                               |                |             |                |
| Post Office Address                                                                                               | CLIFTON                   |                |   |                                                                               |                |             |                |
| City                                                                                                              | BRISTOL                   | State          |   | Zip                                                                           | BS8 4LW        | Country     | UNITED KINGDOM |
| Name of Additional Joint Inventor, if any:                                                                        |                           |                |   | <input type="checkbox"/> A petition has been filed for this unsigned inventor |                |             |                |
| Given Name                                                                                                        | ANTHONY                   | Middle Initial | M | Family Name                                                                   | JONES          | Suffix      |                |
| Inventor's Signature                                                                                              | <i>Anthony Jones</i>      |                |   |                                                                               |                | Date        | May 28, 1998   |
| Residence: City                                                                                                   | ARNHEM-ZUID               | State          |   | Country                                                                       | NETHERLANDS    | Citizenship | UK             |
| Post Office Address                                                                                               | MUNTENDAMPAD 1            |                |   |                                                                               |                |             |                |
| Post Office Address                                                                                               | 6835 BE ARNHEM-ZUID       |                |   |                                                                               |                |             |                |
| City                                                                                                              | ARNHEM-ZUID               | State          |   | Zip                                                                           | 6835           | Country     | NETHERLANDS    |
| Name of Additional Joint Inventor, if any:                                                                        |                           |                |   | <input type="checkbox"/> A petition has been filed for this unsigned inventor |                |             |                |
| Given Name                                                                                                        | HELEN                     | Middle Initial | R | Family Name                                                                   | FINCH          | Suffix      |                |
| Inventor's Signature                                                                                              |                           |                |   |                                                                               |                | Date        |                |
| Residence: City                                                                                                   | BRISTOL                   | State          |   | Country                                                                       | UNITED KINGDOM | Citizenship | UK             |
| Post Office Address                                                                                               | 41 DRUID WOODS - AVON WAY |                |   |                                                                               |                |             |                |
| Post Office Address                                                                                               |                           |                |   |                                                                               |                |             |                |
| City                                                                                                              | BRISTOL                   | State          |   | Zip                                                                           | BS9 1SZ        | Country     | UNITED KINGDOM |
| <input checked="" type="checkbox"/> Additional inventors are being named on supplemental sheet(s) attached hereto |                           |                |   |                                                                               |                |             |                |

## DECLARATION


ADDITIONAL INVENTOR(S)  
Supplemental Sheet

|                                                                                                                   |                                                                                     |                |   |             |                                                                               |             |                |  |  |
|-------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------|---|-------------|-------------------------------------------------------------------------------|-------------|----------------|--|--|
| Name of Additional Joint Inventor, if any:                                                                        |                                                                                     |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                                        | MARTIN                                                                              | Middle Initial | W | Family Name | SOTHERAN                                                                      | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                              |                                                                                     |                |   |             |                                                                               | Date        |                |  |  |
| Residence: City                                                                                                   | BRISTOL                                                                             | State          |   | Country     | UNITED KINGDOM                                                                | Citizenship | UK             |  |  |
| Post Office Address                                                                                               | 24 HOME FARM WAY                                                                    |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                               | EASTER COMPTON                                                                      |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                              | BRISTOL                                                                             | State          |   | Zip         | BS12 3SE                                                                      | Country     | UNITED KINGDOM |  |  |
| Name of Additional Joint Inventor, if any:                                                                        |                                                                                     |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                                        | WILLIAM                                                                             | Middle Initial | P | Family Name | ROBBINS                                                                       | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                              |                                                                                     |                |   |             |                                                                               | Date        |                |  |  |
| Residence: City                                                                                                   | BRISTOL                                                                             | State          |   | Country     | UNITED KINGDOM                                                                | Citizenship | UK             |  |  |
| Post Office Address                                                                                               | 2 WINDSOR TERRACE                                                                   |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                               | CLIFTON                                                                             |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                              | BRISTOL                                                                             | State          |   | Zip         | BS8 4LW                                                                       | Country     | UNITED KINGDOM |  |  |
| Name of Additional Joint Inventor, if any:                                                                        |                                                                                     |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                                        | ANTHONY                                                                             | Middle Initial | M | Family Name | JONES                                                                         | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                              |                                                                                     |                |   |             |                                                                               | Date        |                |  |  |
| Residence: City                                                                                                   | NIJMEGEN                                                                            | State          |   | Country     | NETHERLANDS                                                                   | Citizenship | UK             |  |  |
| Post Office Address                                                                                               | NIJMEEGSEBAAN 45 CB NIJMEGEN                                                        |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                               | HEILIG LAND STICHTING                                                               |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                              | NIJMEGEN                                                                            | State          |   | Zip         | 6564                                                                          | Country     | UNITED KINGDOM |  |  |
| Name of Additional Joint Inventor, if any:                                                                        |                                                                                     |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                                        | HELEN                                                                               | Middle Initial | R | Family Name | FINCH                                                                         | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                              |  |                |   |             |                                                                               | Date        | 11th July 1997 |  |  |
| Residence: City                                                                                                   | BRISTOL                                                                             | State          |   | Country     | UNITED KINGDOM                                                                | Citizenship | UK             |  |  |
| Post Office Address                                                                                               | 41 DRUID WOODS - AVON WAY                                                           |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                               |                                                                                     |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                              | BRISTOL                                                                             | State          |   | Zip         | BS9 1SZ                                                                       | Country     | UNITED KINGDOM |  |  |
| <input checked="" type="checkbox"/> Additional inventors are being named on supplemental sheet(s) attached hereto |                                                                                     |                |   |             |                                                                               |             |                |  |  |

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Approved for use through 9/30/98 OMB 0651-0032  
Patent and trademark Office: U.S. DEPARTMENT OF COMMERCE

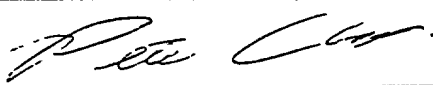
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| DECLARATION                                |  |                                                                                   |  |  |  |                |  |   |  | ADDITIONAL INVENTOR(S)<br>Supplemental Sheet                                  |  |                |  |         |  |                    |  |    |  |
|--------------------------------------------|--|-----------------------------------------------------------------------------------|--|--|--|----------------|--|---|--|-------------------------------------------------------------------------------|--|----------------|--|---------|--|--------------------|--|----|--|
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  | KEVIN                                                                             |  |  |  | Middle Initial |  | J |  | Family Name                                                                   |  | BOYD           |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |  |  |  |  |                |  |   |  | Date                                                                          |  | 4/7/97         |  |         |  |                    |  |    |  |
| Residence: City                            |  | BRISTOL                                                                           |  |  |  | State          |  |   |  | Country                                                                       |  | UNITED KINGDOM |  |         |  | Citizenship        |  | UK |  |
| Post Office Address                        |  | 21 LANCASHIRE ROAD                                                                |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| City                                       |  | BRISTOL                                                                           |  |  |  | State          |  |   |  | Zip                                                                           |  | BS7 9DL        |  | Country |  | UNITED KINGDOM     |  |    |  |
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  | ANTHONY PETER                                                                     |  |  |  | Middle Initial |  | J |  | Family Name                                                                   |  | CLAYDON        |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |                                                                                   |  |  |  |                |  |   |  | Date                                                                          |  |                |  |         |  |                    |  |    |  |
| Residence: City                            |  | BATH AVON                                                                         |  |  |  | State          |  |   |  | Country                                                                       |  | UNITED KINGDOM |  |         |  | Citizenship        |  | UK |  |
| Post Office Address                        |  | 14 SYDNEY BUILDINGS                                                               |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| City                                       |  | BATH AVON                                                                         |  |  |  | State          |  |   |  | Zip                                                                           |  | BA2 6BZ        |  | Country |  | UNITED KINGDOM     |  |    |  |
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  |                                                                                   |  |  |  | Middle Initial |  |   |  | Family Name                                                                   |  |                |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |                                                                                   |  |  |  |                |  |   |  | Date                                                                          |  |                |  |         |  |                    |  |    |  |
| Residence: City                            |  |                                                                                   |  |  |  | State          |  |   |  | Country                                                                       |  |                |  |         |  | Citizenship        |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| City                                       |  |                                                                                   |  |  |  | State          |  |   |  | Zip                                                                           |  |                |  | Country |  |                    |  |    |  |
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  |                                                                                   |  |  |  | Middle Initial |  |   |  | Family Name                                                                   |  |                |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |                                                                                   |  |  |  |                |  |   |  | Date                                                                          |  |                |  |         |  |                    |  |    |  |
| Residence: City                            |  |                                                                                   |  |  |  | State          |  |   |  | Country                                                                       |  |                |  |         |  | Citizenship        |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| City                                       |  |                                                                                   |  |  |  | State          |  |   |  | Zip                                                                           |  |                |  | Country |  |                    |  |    |  |
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  |                                                                                   |  |  |  | Middle Initial |  |   |  | Family Name                                                                   |  |                |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |                                                                                   |  |  |  |                |  |   |  | Date                                                                          |  |                |  |         |  |                    |  |    |  |
| Residence: City                            |  |                                                                                   |  |  |  | State          |  |   |  | Country                                                                       |  |                |  |         |  | Citizenship        |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| City                                       |  |                                                                                   |  |  |  | State          |  |   |  | Zip                                                                           |  |                |  | Country |  |                    |  |    |  |
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  |                                                                                   |  |  |  | Middle Initial |  |   |  | Family Name                                                                   |  |                |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |                                                                                   |  |  |  |                |  |   |  | Date                                                                          |  |                |  |         |  |                    |  |    |  |
| Residence: City                            |  |                                                                                   |  |  |  | State          |  |   |  | Country                                                                       |  |                |  |         |  | Citizenship        |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| City                                       |  |                                                                                   |  |  |  | State          |  |   |  | Zip                                                                           |  |                |  | Country |  |                    |  |    |  |
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  |                                                                                   |  |  |  | Middle Initial |  |   |  | Family Name                                                                   |  |                |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |                                                                                   |  |  |  |                |  |   |  | Date                                                                          |  |                |  |         |  |                    |  |    |  |
| Residence: City                            |  |                                                                                   |  |  |  | State          |  |   |  | Country                                                                       |  |                |  |         |  | Citizenship        |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| City                                       |  |                                                                                   |  |  |  | State          |  |   |  | Zip                                                                           |  |                |  | Country |  |                    |  |    |  |
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  |                                                                                   |  |  |  | Middle Initial |  |   |  | Family Name                                                                   |  |                |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |                                                                                   |  |  |  |                |  |   |  | Date                                                                          |  |                |  |         |  |                    |  |    |  |
| Residence: City                            |  |                                                                                   |  |  |  | State          |  |   |  | Country                                                                       |  |                |  |         |  | Citizenship        |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| City                                       |  |                                                                                   |  |  |  | State          |  |   |  | Zip                                                                           |  |                |  | Country |  |                    |  |    |  |
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  |                                                                                   |  |  |  | Middle Initial |  |   |  | Family Name                                                                   |  |                |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |                                                                                   |  |  |  |                |  |   |  | Date                                                                          |  |                |  |         |  |                    |  |    |  |
| Residence: City                            |  |                                                                                   |  |  |  | State          |  |   |  | Country                                                                       |  |                |  |         |  | Citizenship        |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| City                                       |  |                                                                                   |  |  |  | State          |  |   |  | Zip                                                                           |  |                |  | Country |  |                    |  |    |  |
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  |                                                                                   |  |  |  | Middle Initial |  |   |  | Family Name                                                                   |  |                |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |                                                                                   |  |  |  |                |  |   |  | Date                                                                          |  |                |  |         |  |                    |  |    |  |
| Residence: City                            |  |                                                                                   |  |  |  | State          |  |   |  | Country                                                                       |  |                |  |         |  | Citizenship        |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| City                                       |  |                                                                                   |  |  |  | State          |  |   |  | Zip                                                                           |  |                |  | Country |  |                    |  |    |  |
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  |                                                                                   |  |  |  | Middle Initial |  |   |  | Family Name                                                                   |  |                |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |                                                                                   |  |  |  |                |  |   |  | Date                                                                          |  |                |  |         |  |                    |  |    |  |
| Residence: City                            |  |                                                                                   |  |  |  | State          |  |   |  | Country                                                                       |  |                |  |         |  | Citizenship        |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| Post Office Address                        |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |
| City                                       |  |                                                                                   |  |  |  | State          |  |   |  | Zip                                                                           |  |                |  | Country |  |                    |  |    |  |
| Name of Additional Joint Inventor, if any: |  |                                                                                   |  |  |  |                |  |   |  | <input type="checkbox"/> A petition has been filed for this unsigned inventor |  |                |  |         |  |                    |  |    |  |
| Given Name                                 |  |                                                                                   |  |  |  | Middle Initial |  |   |  | Family Name                                                                   |  |                |  |         |  | Suffix<br>e.g. Jr. |  |    |  |
| Inventor's Signature                       |  |                                                                                   |  |  |  |                |  |   |  | Date                                                                          |  |                |  |         |  |                    |  |    |  |
|                                            |  |                                                                                   |  |  |  |                |  |   |  |                                                                               |  |                |  |         |  |                    |  |    |  |



## DECLARATION

ADDITIONAL INVENTOR(S)  
Supplemental Sheet

|                                                                                                        |                                                                                   |                |   |             |                                                                               |             |                |  |  |
|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|----------------|---|-------------|-------------------------------------------------------------------------------|-------------|----------------|--|--|
| Name of Additional Joint Inventor, if any:                                                             |                                                                                   |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                             | KEVIN                                                                             | Middle Initial | J | Family Name | BOYD                                                                          | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                   |                                                                                   |                |   |             |                                                                               | Date        |                |  |  |
| Residence: City                                                                                        | BRISTOL                                                                           | State          |   | Country     | UNITED KINGDOM                                                                | Citizenship | UK             |  |  |
| Post Office Address                                                                                    | 21 LANCASHIRE ROAD                                                                |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                    |                                                                                   |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                   | BRISTOL                                                                           | State          |   | Zip         | BS7 9DL                                                                       | Country     | UNITED KINGDOM |  |  |
| Name of Additional Joint Inventor, if any:                                                             |                                                                                   |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                             | ANTHONY PETER                                                                     | Middle Initial | J | Family Name | CLAYDON                                                                       | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                   |  |                |   |             |                                                                               | Date        |                |  |  |
| Residence: City                                                                                        | BATH AVON                                                                         | State          |   | Country     | UNITED KINGDOM                                                                | Citizenship | UK             |  |  |
| Post Office Address                                                                                    | 14 SYDNEY BUILDINGS                                                               |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                    |                                                                                   |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                   | BATH AVON                                                                         | State          |   | Zip         | BA2 6BZ                                                                       | Country     | UNITED KINGDOM |  |  |
| Name of Additional Joint Inventor, if any:                                                             |                                                                                   |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                             |                                                                                   | Middle Initial |   | Family Name |                                                                               | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                   |                                                                                   |                |   |             |                                                                               | Date        |                |  |  |
| Residence: City                                                                                        |                                                                                   | State          |   | Country     |                                                                               | Citizenship |                |  |  |
| Post Office Address                                                                                    |                                                                                   |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                    |                                                                                   |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                   |                                                                                   | State          |   | Zip         |                                                                               | Country     |                |  |  |
| Name of Additional Joint Inventor, if any:                                                             |                                                                                   |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                             |                                                                                   | Middle Initial |   | Family Name |                                                                               | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                   |                                                                                   |                |   |             |                                                                               | Date        |                |  |  |
| Residence: City                                                                                        |                                                                                   | State          |   | Country     |                                                                               | Citizenship |                |  |  |
| Post Office Address                                                                                    |                                                                                   |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                    |                                                                                   |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                   |                                                                                   | State          |   | Zip         |                                                                               | Country     |                |  |  |
| Name of Additional Joint Inventor, if any:                                                             |                                                                                   |                |   |             | <input type="checkbox"/> A petition has been filed for this unsigned inventor |             |                |  |  |
| Given Name                                                                                             |                                                                                   | Middle Initial |   | Family Name |                                                                               | Suffix      | e.g. Jr.       |  |  |
| Inventor's Signature                                                                                   |                                                                                   |                |   |             |                                                                               | Date        |                |  |  |
| Residence: City                                                                                        |                                                                                   | State          |   | Country     |                                                                               | Citizenship |                |  |  |
| Post Office Address                                                                                    |                                                                                   |                |   |             |                                                                               |             |                |  |  |
| Post Office Address                                                                                    |                                                                                   |                |   |             |                                                                               |             |                |  |  |
| City                                                                                                   |                                                                                   | State          |   | Zip         |                                                                               | Country     |                |  |  |
| <input type="checkbox"/> Additional inventors are being named on supplemental sheet(s) attached hereto |                                                                                   |                |   |             |                                                                               |             |                |  |  |